INTERNATIONAL
LYMPHOEDEMA
FRAMEWORK

Position document

BEST PRACTICE

FOR THE MANAGEMENT OF
LYMPHOEDEMA - 2ND EDITION

Compression Therapy:
A position document on compression bandaging

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THE INTERNATIONAL LYMPHOEDEMA FRAMEWORK

The International Lymphoedema Framework (ILF) is a UK charity. Its aim is to improve the management of lymphoedema and related disorders worldwide through the sharing of expertise and resources, and by supporting individual countries to develop a long term strategy for lymphoedema. Such a strategy will:

- Raise the profile of lymphoedema nationally and internationally
- Place lymphoedema and its management as a priority on national health care agendas
- Lobby for appropriate financing or reimbursement of lymphoedema care
- Address issues of inequity of provision
- Implement and evaluate lymphoedema services based on best practice
- Create an international lymphoedema community that collectively strives to improve the evidence base for treatment and professional practice
- Improve the lives of lymphoedema sufferers worldwide

The standards of practice for people with lymphoedema outlined in box 1 provide a framework for the ILF and its partner organisations to work towards.

Box 1: Standards of practice for lymphoedema[i]

Standard 1
Awareness and knowledge of lymphoedema within the community

Standard 2
Identification of people at risk of or with lymphoedema

Standard 3
Empowerment of people at risk of or with lymphoedema

Standard 4
Provision of lymphoedema services that deliver high quality clinical care that is subject to continuous improvement

Standard 5
Access to appropriately trained health care professionals

Standard 6
Provision of high quality clinical care for people with cellulitis

Standard 7
Provision of optimal, individualised programmes of care

Standard 8
Provision of multi-disciplinary health and social care

References

i. Standards of practice for Lymphoedema Services (2003) *Lymphoedema Framework Journal.* 10-18

Contents

Foreword

ILF Compression document

This position document on compression bandaging is the first of a series of in-depth documents on aspects of lymphoedema practice and contributes to the second edition of the best practice document. It seeks to draw together the current evidence base supporting compression as well as celebrating the wealth of international variation in the way in which compression bandaging is used in clinical practice. Most importantly, it includes how the challenges of bandaging are tackled in resource poor countries such as India, a feature that was not present in the first edition. The document has been supported by an international editorial board and peer review process including experts in the field of compression therapy to ensure that in addition to presenting the state of the art in compression, it also is clinically useful for practitioners.

Lymphoedema is a chronic disease needing life-long treatment. Among the different therapeutic modalities, compression is the single most important element of treatment for both the initial phase of decongestion (DLT) as well as for long-term maintenance. Compression is vital in order to get the most effective clinical and cost effectiveness outcome of treatment and helping patients to maintain function and have improved appearance. *Management by proper compression may be supplemented with other treatment modalities including skin care, exercise and manual lymphatic drainage but must never be replaced by any other method.*

The focus of this position document is on compression bandaging as one component of DLT. Understanding of general principles and of the mode of action should encourage medical doctors and therapists to accept the burden of the hard challenge of commencing bandaging, even in seemingly hopeless situations and to experience a very rewarding outcome with grateful patients. Equally important is the use of adequate compression in the early stages of lymphoedema, before monstrous tissue deformities occur. To achieve satisfactory results we need well trained, enthusiastic bandagers who are also able to convince their patients about the need to cooperate and to adhere to treatment.

We would be happy if this document could help to improve the lives of many patients who are still left alone and neglected with their lymphoedema. We also hope that professionals will use the document to inform their practice and to ensure they are up to date with the latest research and practice. We also hope that it will contribute to ensuring that lymphoedema care is reimbursed and well delivered across the world.

Christine Moffatt and Hugo Partsch

Summary Statements

Summary of recommendations for compression bandaging in lymphoedema management Level B evidence (based on RCT and systematic review evidence)

Findings from a recent Cochrane systematic review have shown that bandaging and compression hosiery are more effective at reducing and maintaining limb volume over 6 months than using compression hosiery alone.

- Bandaging is used throughout the management of lymphoedema
  - Within a period of intensive DLT
  - In combination with compression hosiery/devices in long term management
  - In palliative care to aid symptom control
- Specialist knowledge and skills are required for safe and effective application

Compression affects the venous, arterial, lymphatic and microcirculation

- Compression is **only contraindicated** in critical ischemia (ABPI < 0.5 or ankle systolic 50mmHg)
- Compression **enhances arterial circulation in patients with mixed disease** (ABPI 0.4-0.8) by removal of oedema
- Compression removes oedema by :
  - reduction in capillary filtration
  - increased lymphatic drainage
  - shift of fluid to non compressed areas
  - breakdown of fibrosclerotic tissue

Criteria for an ideal compression system

- High stiffness, tolerable resting pressures to enhance patient adherence
- Compression is described using the acronym **PLACE** : P=Pressure, LA =Layers, C=Components, E=Elastic property of the single component
- Optimal leg compression levels **(40- 60 mmHg at rest - 60 -90mmHg on standing)**
- Optimal arm compression level **(30mmHg at rest)**
- Different levels of compression for lower and upper limbs are influenced by the effects of gravity and capillary filtration rates
- **Higher levels of pressure** may **impede** lymphatic drainage and damage initial lymphatics
- Compression bandage profiles change over wear time due to oedema reduction (50% pressure drop in 2 hours, two thirds loss after 24 hours)

General recommendations for compression

- Chronic oedema/lymphoedema requires **constant compression,** if discontinued oedema with recur rapidly
- Patient understanding and adherence are critical to sustained outcomes
- Compression **should not impede function** or overall mobility
- Compression bandaging should be continued **until pitting oedema is removed** and long term compression hosiery commenced
- The **greatest oedema reduction occurs in the first week** of treatment

- The exact length of compression bandage duration has not been determined and will vary with individual patient characteristics (1 to 4 weeks)
- Compression **must** be accompanied by other elements of DLT (skin care, exercise and MLD)

Problems with achieving correct compression levels

- Graduated compression profiles are **rarely** achieved in practice according to Laplace's law, although compression profiles improve with training
- Traditional approaches to the filling of enhanced skin folds in Lymphoedema may result in a **negative pressure** gradient
- **Excessive padding reduces** the compression applied to a limb

Assessment

The choice and use of compression bandages are determined by:

- Site, stage and severity of the lymphoedema (ISL classification and degree of swelling)
- Co-morbidities: mobility, obesity, psychological tolerance, adherence
- Arterial status of the limb
- Social situation and level of support
- Goals of treatment
- Assessment must be continuous to ensure the best volume reduction is achieved

Skin care problems with compression bandaging

- Chronic disturbance of lymph flow causes chronic inflammation in the affected area
- Skin problems include: thickening of skin and underlying tissues, hyperkeratosis, papillamatosis, hyperpigmentation, fibrosis, deep skin folds
- Meticulous skin care regimes are required to increase skin integrity and prevent maceration and infection
- General daily skin care; wash and dry thoroughly, use of emollients, avoidance of allergens, monitor for skin breaks

Bandage adaption

- Limb shape distortion requires adaption of the application of compression materials
- Low cost solutions can be used in developing countries (as seen in the example form India)
- Compression bandaging can be very difficult to wear for many patients in hot climates or in demanding physical jobs
- Low cost materials are required to improve access throughout the world
- In many parts of the world patients and carers undertake self bandaging and require training

Compression for the palliative patient

- Physical and psychological needs guide the use of compression in the palliative patient
- Outcomes of comfort and function may be more important than volume reduction
- Compression pressure may need to be reduced by removing layers or decreasing tension of bandage application
- Low resting pressures are better tolerated
- Skin is very friable and requires constant review
- Extra padding may be needed for vulnerable areas of pressure
- Limb positioning may enhance the effects of bandaging
- Minimal levels of compression can reduce or eliminate lymphorrhoea.
- Control of other symptoms will enhance the tolerance of compression

About this document

Lymphoedema is a chronic, progressive and often debilitating condition caused by the organic or functional deficiency of the lymphatic system[1]. Due to its chronic nature, lymphoedema requires ongoing treatments that consider lymphatic anatomy and function[2]. It is estimated that lymphoedema impacts upon more than 120 million world-wide. Despite this prevalence, explicit assessment methodologies, effective means of treatment and comprehensive management strategies remain largely inadequate. Recent research and growing awareness of the condition has however, offered well-founded interventions for the condition[3].

In support of this growing worldwide awareness, this second edition, entitled 'Best Practice for the Management of Lymphoedema - Compression Therapy: A position document', represents an international multidisciplinary initiative led by the International Lymphoedema Framework (ILF) in association with the American Lymphedema Framework Project (ALFP) and the Canadian Lymphedema Framework (CLF). For clarity and simplicity, this document pertains to compression bandaging only; other compression methods such as Intermittent Pneumatic Compression (IPC) and hosiery will be the topic of a later document. The ILF editorial committee believes that a large, bulky document which attempts to cover all aspects of decongestive lymphatic therapy (DLT) would not do justice to the needs of patients and practitoners world-wide. Therefore, it was decided to build a compendium of individual, in-depth documents on topics which fall under the DLT 'umbrella'. Each discreet section, building into a final 12-topic document, provides a model for best practice in the assessment, treatment and continuing management of lymphoedema. The document contains broad practice standards applicable to the international lymphoedema community for future review, consensus building, and translation. Naturally, it is expected that practitioners will have undertaken the relevant training and educational requirements before using the guidance here.

This document derives its spirit from the first edition[4]. Within the limitations outlined below, it reflects the current evidence-base. The challenge of creating and updating this document is primarily related to the paucity of randomised controlled (clinical) trials (RCTs) in the field. Where RCTs are not widely available, other sources of evidence are considered valid approaches to best practice guideline development[5]. For the purposes of this document, literature search, expert review and consensus were used.

Document terminology

As with any clinical discipline, terminology often varies between countries. While the ILF and its international framework partners are working towards a consensus on terminology in respect to lymphoedema, for the purposes of this document the following terms will be used:

- Decongestive lymphatic therapy (DLT) (also known as complete decongestive therapy (CDT) or complex decongestive physical therapy)[5]
- Inelastic bandages (also known as short-stretch bandages)
- Lymphoedema compression bandaging (LCB) (also known as multilayer lymphoedema bandaging and multi-component lymphatic bandaging)

Limitations

The ILF would like to acknowledge that while the best practice statements contained within this document are as contemporaneous as possible, based on the systematic review, they are largely derived from studies published in English. For future editions of the Best Practice Documents, the ILF will be working closely with their international partners, ensuring that studies published in their respective countries will be reviewed and included where appropriate.

References

1. International Society of Lymphology Executive Committee (2009) *The Diagnosis and Treatment of Peripheral Lymphedema.* Consensus Document of the International Society of Lymphology. Lymphology. 42. No.2, 51-60
2. Foldi M, Foldi E, Kubik S. (eds) (2006) *Foldi's textbook of Lymphology for Physicians and Lymphedema Therapists. (2nd ed)* Elsevier Urben & Fisher, Munchen
3. Stout N. (2009) Early Diagnosis and Treatment Intervention for Lymphedema – The New Standard of Care. *Lymphlink.* Vol 21, No 1 1-3
4. Lymphoedema Framework (2006) Best Practice for the Management of Lymphoedema. *International Consensus.* MEP Ltd, London
5. Rockson SG, Miller LT, Senie R, *et al.* (1998) American Cancer Society Lymphedema Workshop. Workgroup III: Diagnosis and management of lymphedema *Cancer.* 83 (12 Suppl American): 2882-5

CHAPTER 1
A contextual view of compression bandaging for lymphoedema

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A combination of techniques is used in the management of lymphoedema. These include:

- manual lymphatic drainage (MLD)
- compression therapy
- exercise and skin care

These have been called the cornerstones of lymphoedema management in the literature[1]. Compression bandaging plays a central role in the management of all forms of chronic oedema and lymphoedema[2].

Problems of definition

International variations in the use of the terms to describe this multi-modal treatment exist. Formerly, the terms complex decongestive therapy (CDT), complex physical therapy (CPT), or complex decongestive physiotherapy (CDP) were used. International consensus in 1998 changed this terminology to decongestive lymphatic therapy (DLT), as this clarified that treatment involved the lymphatic system. Terms such as complex or complete were also thought to be subjective and confusing and were therefore abandoned. More recently, the first edition of the International Lymphoedema Framework's Best Practice Document[3] adopted the term intensive treatment. The reason for this change was the recognition that treatment could involve other modalities than those traditionally described and that the term DLT was too restrictive.

Despite the changes in terminology, there continues to be much debate with wide variation in the performance of MLD techniques, use and application of compression systems, exercise and skin care regimens. This contributes to the lack of evidence on the effect of DLT and the challenge of comparing studies that use DLT in many different ways. The heterogeneity of the population requiring DLT is a further challenge in evaluating the outcomes of treatment.

Recent systematic reviews show that bandaging and compression hosiery when used in combination, are more effective at reducing and maintaining limb volume over six months than using hosiery alone[4]. The systematic reviews call for improved clinical trials and the ability to understand the relative contribution of the different aspects of treatment. To date, very little research has been undertaken on the many different combinations of bandages or different bandage application techniques and practice is largely based on tradition and clinical experience.

Understanding when bandaging is used

While it is recognised that multi-layer bandaging is used during a period of DLT (intensive treatment), it may also be used as part of long-term management in certain groups who cannot wear compression hosiery. Bandaging may be very effective in aiding symptom control in patients with cancer-related lymphoedema and frail patients with complex medical problems[3]. Patients may also choose to self-bandage as part of their long-term management plan.

It is essential that practitioners understand how application techniques can affect the performance of bandage systems. Traditional approaches to multi-layer lymphoedema bandaging use inelastic bandages over padding or foam layers. Technological advances in compression materials are influencing our understanding of features required in an ideal compression system and new compression devices are emerging that bridge the gap between bandaging and use of compression hosiery.

Understanding mode of action

The mode of action of compression in lymphoedema management has been poorly understood and has relied heavily on literature from venous disease[5]. Recent research is beginning to unravel the mechanisms of action in compression and will therefore allow greater clarification of the optimal compression profiles for patients with arm and leg oedema[6,7]. Traditional methods of application involving extensive padding are also being reconsidered with the focus on increasing patient function and overall mobility.Underpinning principles such as the use of Laplace's law in compression bandaging are being challenged, as methods of application show that appropriate gradients of pressure are rarely achieved and extensive padding reduces the overall effectiveness[8].

Outcomes of compression bandaging

The primary outcome in most compression studies on lymphoedema is change in volume at the end of treatment. However, there is no internationally agreed definition of what an ideal volume reduction should be and different methods of measuring limb volume add to this complex debate. Other outcomes may be more important to heath care systems than the change in volume. These include:

- the cost-effectiveness of care through improved clinical outcome and appropriate use of health resources
- the potential to reduce episodes of cellulitis requiring hospitalisation
- a reduction in patients requiring expensive episodes of DLT

Improved clinical trials in compression bandaging must address these issues and implement the agreed international standards for undertaking such studies[9]. This includes the ability to understand the 'dose' of compression being used throughout a trial using sub-bandage pressure measurement to define stiffness. This will help to define which bandaging systems are most appropriate for different patient groups. It will also help to define the optimum length of treatment. Current evidence suggests that the majority of fluid is removed during the first treatment episodes; however, many patients require much longer treatment and there are no agreed standards of how long bandaging should be performed or the criteria for when it should be stopped[10].

Health system challenges

Lack of reimbursement for lymphoedema care due to the dearth of research is a major international challenge and currently reduces access to appropriate compression bandaging in many parts of the world. In developing countries, the cost of bandaging is often prohibitive. In this document, an example of how this has been overcome in India is presented *(Chapter 7)*. However, resource-poor countries urgently need low cost and effective compression bandages. They also face the additional challenge of lack of access to healthcare and approaches that involve self care and involvement of family and the local community have much to teach the western world.

Professional challenges

Management of patients with complex lymphoedema requires highly skilled, specialist practitioners. Patients with late-stage lymphoedema may have extreme limb distortion requiring adaptation of both the materials used and the application technique[3]. Morbid obesity is on the increase and it is suggested that 80% of obese people will suffer with lymphoedema, which is generally complex to bandage[11]. Research in the United Kingdom (UK) and Canada show that many lymphoedema services are treating more complex patients with multiple co-morbidities and patients who have not been diagnosed or offered treatment[12].

Current approaches to DLT are labour intensive, requiring daily treatment for several weeks. Practitioners frequently have to modify treatment to meet the complex clinical and psychosocial needs of patients. A major frustration for both professional and patient is maintaining the improvement achieved during DLT once this has finished. Rebound oedema is a common and complex clinical challenge that requires effective compression solutions.

Patient challenges

Traditional bandaging used in DLT requires considerable commitment from the patient to attend for daily treatments. Patients recognise the effectiveness of the treatment but many find it restrictive influencing their work and social activities[13]. Immobile patients often have difficulty attending for bandaging and require help at home to accommodate the compression when it is applied. A recent clinical trial using a new compression method (Coban® 2 system) showed that the most effective clinical and cost outcome was achieved in patients being seen twice weekly[14]. However, the bandages used maintained their performance over a number of days. The same study showed that patients had improved function when compared to a traditional inelastic system. Younger patients are requesting the use of bandages they can safely apply themselves. Lack of access to healthcare support will require the lymphoedema community to develop and evaluate effective compression systems that can be safely used in the patient's home. New compression wraps such as CircAid® Juxtafit™ can be applied by even the most immobile patient and can be used in combination with bandaging or compression hosiery with good effect[15].

The recommendations in this document are based on physiological principles and the current evidence base. While this document focuses on one element of DLT, compression bandaging, it is essential that all other components of care are effectively delivered to patients for whom there is a clear clinical diagnosis and treatment plan.

References

1. Földi E, Jünger M, Partsch H. (2005) The science of lymphoedema bandaging. *EWMA Focus Document: Lymphoedema bandaging in practice.* MEP Ltd, London
2. Partsch H (2003) Understanding the pathophysiological effects of compression. In: *EWMA Position Document 2: Understanding Compression Therapy.* MEP Ltd, London
3. Lymphoedema Framework (2006) Best Practice for the Management of Lymphoedema. *International Consensus.* MEP Ltd, London
4. Badger C, Preston N, Seers K, *et al.* (2004) Physical therapies for reducing and controlling lymphoedema of the limbs. *Cochrane Database Syst Rev.* 18 (4): CD003141. Review
5. Partsch H, Damstra RJ, Mosti G. (2011) Dose finding for an optimal compression pressure to reduce chronic edema of the extremities. *Int Angiol.* 30. (6): 527-33
6. Lamprou DA, Damstra RJ, Partsch H. (2011) Prospective, randomized, controlled trial comparing a new two-component compression system with inelastic multicomponent compression bandages in the treatment of leg lymphedema. *Dermatol Surg.* 37 (7): 985-981
7. Damstra RJ, Partsch H. (2009) Compression therapy in breast cancer-related lymphedema: A randomized, controlled comparative study of relation between volume and interface pressure changes. *J Vasc Surg.* 49 (5): 1256-63
8. Schuren J. (2011) Compression unravelled. Margreff Druck GmbH, Essen Germany
9. Partsch H, Clark M, Bassez S, *et al.* (2006) Measurement of lower leg compression in vivo: recommendations for the performance of measurement of interface pressure and stiffness: consensus statement. *Dermatol Surg.* 32 (3): 224-232
10. Johansson K, Albertsson M, Ingvar C, *et al.* (1999) Effects of compression bandaging with or without manual lymph drainage treatment in patients with postoperative arm lymphedema. *Lymphology.* 32: 103-110
11. Fife C, Carter MJ (2008) Lymphoedema in the morbidly obese patient: unique challenges in a unique population. *Ostomy Wound Management.* 54 (1): 44-56
12. Morgan PA, Murray S, Moffatt CJ, *et al.* (2012) The challenges of managing complex lymphoedema/chronic oedema in the UK and Canada. *Int Wound J.* 9: 54–69
13. Morgan PA, Murray S, Moffatt CJ, *et al.* (2011) The experience of patients with lymphoedema undergoing a period of compression bandaging in the UK and Canada using the 3M™ Coban™ 2 compression system. *Int Wound J.* 8: 586-598
14. Moffatt CJ, Franks PJ, Hardy D, *et al.* (2011) A preliminary randomized controlled study to determine the application frequency of a new lymphoedema bandaging system. *Br. J. Dermatol.* Nov 7. doi: 10.1111/j.1365-2133.2011.10731.x. [Epub ahead of print]
15. Damstra R, Partsch H. (2012) Prospective, Randomized Controlled Trial Comparing the Effectiveness of adjustable compression Velcro-wraps versus Inelastic Multilayer Compression Bandages in the initial Treatment of Leg Lymphedema. *J Vasc Surg.* (In print)

CHAPTER 2
An overview of the science behind compression bandaging for lymphoedema and chronic oedema

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Pathophysiology of lymphoedema

Lymphoedema may manifest as swelling of one or more limbs and may include the corresponding quadrant of the trunk[1-3]. Swelling may also affect other areas such as the head, neck, breast or genitalia. Lymphoedema is generally classed as:

- Primary: caused by a congenital disease or primary abnormality of the lymphatics and can present at birth, early or late in life
- Secondary: lymphoedema occurs due to damage of the lymphatic system including treatment for cancer, trauma, and venous disease
- Chronic oedema: a broad term used to describe oedema of greater than 3 months' duration, where normal lymphatics have failed to remove the overload of tissue fluid; primarily caused by other pathologies[4-6]

The structural and functional abnormalities of lymphatics frequently overlap. Aplasia and hypoplasia, obstruction, valvular incompetence and loss of contractility due to loss of movement for example, are the main reasons for organic lymphatic damage (low output failure). Dynamic insufficiency (high output failure) occurs due to an overload of filtration into the tissue, due for example, to infection, nephrotic syndrome, trauma, early stage chronic venous insufficiency (CVI), dependency, or cardiac insufficiency[7].

Lymph stagnates with the accumulation of protein, macromolecules, hyaluronan, fat, water and cell debris in the interstitium[8,9]. Hypertension develops in the lymphatics that are still functioning, causing further damage[10]. Secondary degenerative changes in the tissue and chronic inflammation develop due to the impaired lymph transport of immune cells. This lowered immunity can lead to a cycle of recurrent episodes of cellulitis that further damage the lymphatics, leading to worsening oedema and tissue changes such as the laying down of fibrosis and adipose tissue[11].

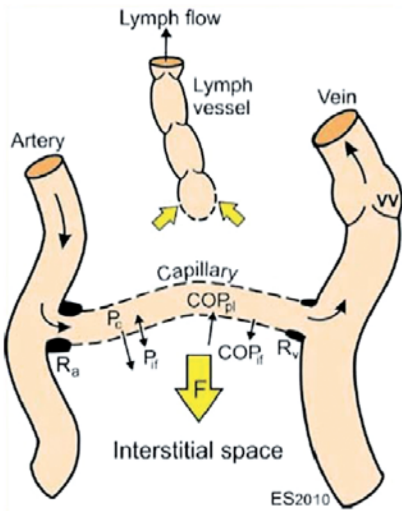
How does oedema form? Understanding Starling's equilibrium

Oedema (fluid collection in the interstitium) develops because of a complex interaction that involves the permeability of the capillary wall and the hydrostatic and oncotic pressure gradients that exist between the blood vessels and the tissues. Oedema will form when net capillary filtration in the affected site exceeds lymphatic drainage[12,13]. Figure 1 shows a schematic drawing of the factors influencing trans-capillary fluid-exchange (Starling's equilibrium).

Filtration of fluid is influenced by the:

- hydrostatic pressure gradient between the fluid in the capillary and that in the interstitial space
- opposing colloid osmotic pressure gradient due to the plasma proteins present in a higher concentration within the capillary
- permeability of the capillary wall for large molecules varies between different body regions and is rather low (but not zero) in the subcutaneous tissue. Thus, in peripheral tissues, large molecules may penetrate the capillary membrane regulating the colloid osmotic equilibrium. In cases of impaired lymph-drainage this may be the starting point for a progredient chronic inflammatory reaction

Figure 1: Schematic illustration of the factors involved in trans-capillary fluid transport[14]



Ra and Rv are the pre- and postcapillary vascular resistances, Pc and Pif are the hydrostatic pressures in the capillary and the interstitial fluid, respectively, COPpl and COPif are the colloid osmotic pressures of plasma and interstitial fluid. VV denotes venous valve, and F is the net filtration of fluid. (Courtesy of E. Stranden and RSM publishing)

In contrast to the classical concept stating the majority of tissue fluid will be reabsorbed into the blood stream via venules, recent research has taught us that in peripheral tissues, reabsorption is entirely via the lymphatic system[13]. This important finding underlines the involvement of lymphatic drainage in every kind of oedema.

Lymphatic drainage is determined by:

- the functional integrity of the lymphatic circulation (including initial lymphatics and large lymph collectors showing spontaneous contractions which propel lymph fluid toward the lymph nodes)
- the extrinsic muscle pump during exercise and movement

Starling's equation indicates that when compression is applied it will counteract capillary fluid filtration because the compression increases the local tissue pressure causing lymph reabsorption *(Figure 1)*.

How compression works

Effects of compression on venous circulation

In a standing position, blood flows slowly through the veins. The hydrostatic pressure at the foot when standing still, corresponds to the weight of the column of blood between the right atrium and the foot; 80-100mmHg in an adult person of normal height. Due to the calf muscle action when walking, the pressure falls to between 10–20mmHg in people with competent valves in the veins.

In patients with deep vein damage or varicosities, blood will oscillate up and down the veins causing a progressive rise in pressure in the venous circulation, known as ambulatory venous hypertension. The rise in pressure causes oedema to form in the interstitium.

Compression works through a number of mechanisms on the venous system. These include:

- increased venous flow velocity
- a reduction in venous reflux
- a reduction in blood volume in the legs due to the reduction of the vein diameter of major veins and the movement of blood to the central parts of the body
- increased venous flow towards the heart (may enhance the preload of the heart by 5%)[15]

Effects of compression pressure and stiffness on venous return

The level of compression required for treatment of venous disease is influenced by the body position. Venous diameters can be reduced in the lying position by pressures as low as 10-20mmHg (for example, the pressure of anti-embolic stockings). Pressures in excess of 30mmHg do not further improve venous flow velocity when the patient is lying down. However, when standing the pressure required by compression is much higher to compensate for the hydrostatic pressure and the venous hypertension. A working pressure of 60-90mmHg is now recommended as an appropriate pressure profile[16]. Such high pressure peaks can only be achieved by stiff material applied with a pressure in the lying position between 40 and 60mmHg.

The term 'stiffness' characterises the elastic property of a compression device on the extremity and is determined by the pressure increase caused by an enlargement of the limb by muscle contraction. By standing up or by walking, elastic material as used in compression stockings will give way and lead only to a modest increase of compression pressure, whereas stiff, non-yielding material will cause a much higher pressure increase[17] *(Figure 2)*.

The difference between the sub-bandage pressure measured on the distal lower leg above the ankle area in the standing, minus the lying position is the 'Static Stiffness Index' (SSI)[17] *(Figure 2)*.

Figure 2: Pressure tracings measured under elastic (top) and inelastic (bottom) bandages at the medial distal leg in the lying position

Both bandages are applied with a resting pressure of 40mmHg. Dorsiflexions and even toe movements produce pressure peaks which are much higher under inelastic than under elastic bandages. Upon standing, there is an immediate increase of pressure by 30mmHg under the inelastic bandage, and only a 10mmHg increase under the elastic bandage. The difference between standing and lying pressure is the 'Static Stiffness Index'. The pressure amplitudes during movement correspond to the massaging effect of the material.

Standing can be considered as a snapshot during the cycle of one single step. Therefore, the standing pressure comes very close and correlates very well with the maximal pressure peaks during walking. This is why the SSI is a very plausible parameter, characterising the gap between a high, effective working pressure and a tolerable resting pressure[17].

Facing the therapeutic challenge to intermittently compress leg veins during walking in order to reduce reflux and increase expelled volume of the calf pump during muscle systole, we would like to see pressure peaks under the bandage of 60-90mmHg or more. This would also mean that pressures of this magnitude should be reached during standing. If such pressure should be achieved by using an elastic material with an SSI of for example, 5mmHg, this would mean that the resting pressure in the lying position would need to be 55-85mmHg which would not be tolerated. Thus, a bandage with a SSI of 20-30mmHg is required. Subtracted from peak pressures of 60-90mmHg, this would cause a pressure of 30-60mmHg in the lying position, which is well tolerated. However, upon standing, the sub-bandage pressure would immediately increase by 20-30mmHg, adjusting to overcome the high intravenous increase pressure in the upright position. Such 'intelligent compression products' for the treatment of venous problems are therefore characterised by a high working pressure and a tolerable resting pressure.

Inelastic or non-stretch or material bandages, along with cohesive or adhesive products, belong to this category of products. When multi-component bandages are used, the addition of each bandage layer will increase the stiffness of the final bandage because of the increase of friction between the layers. This is why multi-component bandages comprising single layers with elastic material, may produce a final bandage with considerable stiffness[18].

Effects of compression on the arterial circulation

External compression pressure should never exceed the intra-arterial pressure. This will barely be possible in a subject without arterial pathology in whom the intra-arterial pressure in the lower extremities will equal the blood pressure measured in the arm. By standing up, the weight of the blood column (~80mmHg) will add to the systolic pressure in the lying position, so that pressures over 200mmHg will be measured in the normal individual. A conventional bandage will never exceed such a pressure. Extreme caution is necessary in patients with a reduced intra-arterial pressure due to arterial occlusive disease.

For patients with venous disease or with chronic oedema and concomitant arterial occlusions, comparing lower extremity systolic arterial pressure measurements with the values of systolic arm pressures can aid assessment of the severity of the arterial occlusive disease and guide adjustment in the pressure of a compression device to that of the intra-arterial pressure. This is easily done with a pocket Doppler instrument and application of a sphygmomanometer cuff over the ankle (not the calf); the quotient between the pressure measured at the ankle and the upper arm in the lying position is the Ankle Brachial Pressure Index (ABPI) and should be normally greater than 1.0. An ABPI measurement of lower than 0.5 is defined as critical ischaemia and is a strict contraindication to compression therapy.

In patients with calcified and incompressible ankle-arteries, or in those with massive oedema, such measurements are not reliable and need to be replaced by other screening methods such as pulse-curve analysis.

In all cases, venous incompetence and chronic oedema will worsen the sequelae of arterial disease. This is because venous hypertension reduces the intravascular pressure-gradient between the arterial inflow and the venous return so that the perfusion pressure driving nutrients into the capillaries and from there into the undernourished tissue will be reduced. Conversely, oedema will push blood capillaries apart so that the distances between each blood capillary and the malnourished tissue cells will increase, impeding the transport of nutrients.

Compression is able to increase the reduced arterio-venous pressure gradient and to reduce the distance between nourishing capillaries by removal of oedema. It has been demonstrated that in a group of patients with mixed, arterial-venous ulcers and an ABPI between 0.42 and 0.8, inelastic compression bandages applied with a pressure up to 40mmHg did not reduce arterial flow, but increased the venous pumping function. Only higher pressures led to a reduction of the toe pressure[19]. As previously shown, even in individuals without arterial pathology[20], an increase of blood flow under the bandage was observed.

This, together with the massaging action of a stiff bandage producing hyperaemia in a similar way as intermittent pressure pumps, is the reason for recommending walking exercises with not too strongly applied stiff bandages as the basis of conservative treatment in patients with mixed, arterial-venous –lymphatic disease.

How compression affects the microcirculation

Over recent years, several important findings concerning compression effects on the microcirculation have been published. Some investigations have been performed with pneumatic compression pumps, offering a well standardised model for the intermittent compression occurring during walking wearing a non-elastic bandage.

The effects of compression on the microcirculation include [21-28]:

- reduction of capillary filtration
- increase of microcirculatory blood flow velocity
- prevention of adhesion of neutrophils and monocytes to the capillary endothelium and reduction of inflammatory cells
- reduction of pro-inflammatory cytokines and of pro-inflammatory environment (for example, matrix metalloproteinases) in ulcer patients
- anti-inflammatory, analgesic and anti-thrombotic, vasodilatory effect by release of biochemical mediators from endothelial cells during intermittent compression (tissue plasminogen activator, nitric oxygen, tissue factor pathway inhibitor)

How compression affects oedema

Our current understanding of how compression works on patients with chronic oedema and lymphoedema remains poor and relies heavily on venous research. However, this is closely related to the lymphatic side. The dramatic reduction of oedema is thought to be mainly due to:

- a reduction of capillary filtration
- an increase of lymphatic drainage
- a shift of fluid into non-or less-compressed parts of the body
- the breakdown of fibrosclerotic tissue

Reduction of capillary filtration

Following Starling's law, filtration is dominated by the hydrostatic pressure (determined by body position) in the venules and capillaries. Capillary pressure is more sensitive to changes in venous pressure than arterial pressure. Because of the low post-capillary resistance, the level of venous pressure mimics capillary pressure.

Arterially, vasoconstriction reduces capillary pressure, which is the basis for local veno-arterial reflexes. If these are intact, an increase in venous pressure will lead to constriction of arterioles, excluding large areas of filtrating capillaries. This mechanism based on an axon-reflex protects dependent body regions of normal individuals from developing massive oedema when in the upright position. This veno-arterial response is suspended in patients with arterial occlusive disease and in patients with peripheral neuropathy (for example, in diabetes). Intermittent pneumatic compression (IPC) may increase skin blood flow through transient suspension of local vaso-regulation[29-31].

Compression reduces capillary filtration depending on the exerted pressure and the stiffness of the compression material. Material with low stiffness but higher pressure may achieve a reduction of capillary filtration rate to an extent similar to material with high stiffness but lower pressure[32]. Compression reduces the water filtration more than the protein content of the tissue, thereby increasing the oncotic pressure of the interstitium[33]. This is why continuation of sustained compression will be necessary after initial decongestion.

Increase of lymphatic drainage

The effect of compression on lymphatic drainage is complex and not fully understood. Traditionally it was thought that 90% of the total blood volume that drained through the microcirculation returned to the heart via the venous system, with the remaining 10% carried by the lymphatics. However, a recent study found that the difference between the venous pressure and interstitial pressure was too low to create the physiological state for reabsorption, and indicated that in peripheral tissues, 100% of liquid removal occurred through the lymphatic circulation[13]. These findings underline the importance of the lymphatic drainage, which will always be compromised in a patient with chronic oedema.

Compression increases tissue pressure resulting in an increased tension on the anchoring filaments of the initial lymphatics which will be pulled open. Valves in these initial lymphatics provide unidirectional flow towards the lymph collectors in which rhythmic autonomous contractions provide the main force of further lymph drainage. By measuring the pressure in lymphatic capillaries it could be demonstrated that decongestive lymphatic therapy (DLT), using inelastic compression bandages reduced the increased intra-lymphatic pressure significantly[10].

In a study measuring lymph flow and pressure in healthy individuals and in patients with different stages of obstructive lymphoedema, the effect of movement, manual massage, intermittent pneumatic compression, and compression bandages was investigated. Each intervention provided a variable effect, seemingly depending on the underlying type of lymphatic damage. In a patient with obstructive lymphoedema it could be demonstrated that the lymphangion's contracting force reached maximal peak values during calf muscle contractions if the compression pressure did not exceed 40mmHg[11].

Different methods to visualise lymph drainage by injecting dyes or radioactive tracers have been used to demonstrate the effect of different compression devices on the lymphatic drainage. Due to often non-homogenous clinical situations and different techniques, the results are sometimes difficult to interpret and controversial. Most studies have been performed with intermittent pneumatic compression. A recent study using the near-infrared (NIR) fluorescence imaging technique showed very instructive pictures of an increased lymph propulsion under the pump[34].

Only a few studies have investigated the influence of lymph bandages on the lymphatic drainage. In patients with post-thrombotic syndrome the sub-facial lymph transport assessed by intramuscular injection of radioactive colloids is reduced. Inelastic compression bandages and walking exercises are able to increase this damaged subfascial lymph drainage[35,36].

Shift of fluid into non-compressed parts of the limb

Compression may shift fluid into non-compressed parts of the limb. This can be prevented by using compression of toes and fingers and by using additional special compression techniques, manual methods, or taping at the root of the extremity.

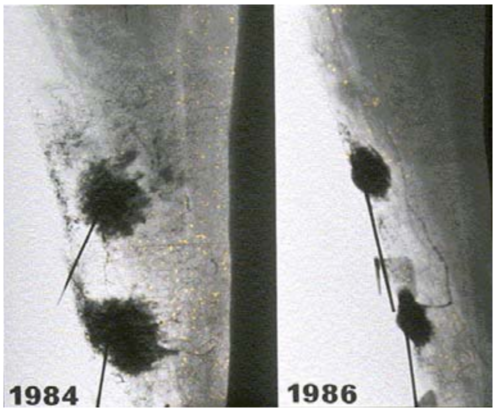
Olszewski *et al* measured tissue fluid pressure and flow under the skin in the subcutaneous tissue of limbs with lymphoedema at rest and during manual and pneumatic compression under various pressures and inflation timing[37]. It was demonstrated that tissue fluid pressures in the subcutaneous tissue ranged from -1 to +10mmHg and did not differ from those measured in normal subjects. During manual massage, the applied force generated pressures ranging from 100 to 150mmHg. Compression at a distance of 3cm from the location of the pressure sensor did not show any rise in pressure. Tissue fluid flow during manual compression occurred only during pressing of tissues and stopped immediately after cessation of massage. In a recent study the same group demonstrated that radioactive tracer shifted by IPC did not cross the inguinal crease[38].

Breakdown of fibrosclerotic tissue

Defective lymph drainage leads to tissue fibrosis and fat deposition which is caused by a chronic inflammatory response due to a dysregulation of molecular mechanisms. Földi et al have demonstrated that pro-inflammatory cytokines and receptors for growth factors, upregulated in lymphoedema patients, become downregulated after DLT[39].

An instructive model for the efficacy of compression therapy to soften tissue fibrosis is lipodermatosclerosis in patients with advanced venous insufficiency[40]. Good compression is not only able to improve the clinical appearance but also to normalise the disturbed lymphatic drainage in such areas[41] *(Figure 3)*.

Figure 3: Intracutaneous injection (indirect lymphography)



Water-soluble contrast *media is delivered into a lipodermatosclerotic area above the inner ankle shows dermal backflow and extravasation of the dye (left). After proper compression therapy for two years lipodematosclerosis was resolved, indirect lymphography shows normal lymph collectors leading out from the deposits of the contrast medium (right)*

What is the evidence for compression?

Data from randomised controlled trials (RCTs) supporting specific forms of compression therapy are rather sparse and difficult to analyse, mainly due to the broad diversity of treatment modalities and measured outcome parameters. Most studies concentrating on volume reduction have compared compression versus the same compression in addition to manual lymphatic drainage (MLD) or other adjunctive treatments. Different compression devices were only compared sporadically. Table I gives an overview of the studies.

The first step to compare one compression modality with another is a short-term trial in which the volume reduction of a lymphoedematous extremity is measured and at the same time the exerted pressure of the device is registered[43,44]. Recommendations for future trials to evaluate compression therapy in lymphoedema patients have been worked out by an international consensus group[45].

Table 1: Summary of compression studies

Reference/ method	Outcome
#43 Low pressure bandages/high pressure bandages , arms, n=36	Greater volume reduction with low pressure bandages (ns), ***2 and 24 hours***
#44 Two-component bandage/ multicomponent bandage legs, n=30	Greater volume reduction with two component bandages (ns) ***2 and 24 hours***
#46 Review: Physical therapies 3 RCT's, n=150	MCS beneficial, manual lymph drainage no extra benefit. Bandage + MCS better than MCS alone
#47 Bandages /MCS Arms and legs, n=90	Inelastic bandage reduce volume more than MCS, ***24 weeks***
#48 Sleeve/sleeve + intermittent pneumatic compression (IPC) - Arms, n=74	Volume reduction, > 25% ***6 months*** No significant difference
#49 IPC + sleeve/decongestive lymphatic therapy (DLT) - Arms, n=28	No significant difference, ***2.5 years***
#50 IPC+ bandage/manual lymphatic drainage (MLD) + bandage - Legs, n=36	Greater volume reduction with IPC, ***10 days***
#51 Standard care/standard care + MLD, Arms, n=42	No significant difference, ***12 months***
#52 Band/Bandages + MLD, Arms, n=42	Mild additive effect of MLD on volume reduction, ***4 weeks***
#53 IPC+DLT/ DLT alone Arms, n=23	Additional mean volume reduction by IPC, ***6 months***
#54 DLT/physiotherapy, Arms, n=53	DLT better than physiotherapy, ***4 weeks***
#55 IPC/self-massage+ sleeve, Arms, n=10	Greater volume reduction with IPC (not significant). ***42 days***
#56 Exercise + sleeve/exercise alone, Arms, n=21	No significant difference ***6 months***
#57 Kinesio tapes + DLT/Bandage+DLT, Arms, n=41	No significant (ns) difference, ***3 months***

MCS - medical compression stockings
ns – not statistically significant
/ - group A vs group B

Search for optimal compression pressure

The pressure range required to effectively narrow leg veins in different body positions could be evaluated by different experiments using duplex ultrasound or magnetic resonance imaging as clear indicators[16,42]. Details are given in the paragraph, 'pressure and stiffness of compression products'.

In contrast to the venous side, only few data are available searching for optimal pressure ranges to reduce oedema. More studies following standardised protocols are needed both for the upper and lower extremities[58]. Recent studies have challenged the common recommendation that the compression pressure should be as high as can be tolerated by the patient[59].

Measuring the volume reduction of swollen limbs by compression bandages different pressure ranges were found to be maximally effective for arm and for leg oedema. In breast cancer related arm lymphoedema, inelastic bandages with a pressure between 20-30mmHg achieved a higher degree of volume reduction (-2.3%, 95% confidence interval [CI] 1.0-3.6) than high pressure bandages applied with a pressure between 44-68mmHg (-1.5%, 95% CI 0.2-2.8) after 2 hours[60]. In patients with leg oedema, compression stockings in the range between 20 and 40mmHg showed a positive correlation between exerted pressure and volume reduction. However, bandages applied with an initial resting pressure of more than 60mmHg resulted in a decreasing volume reduction[61]. From these studies it may be concluded that there is obviously an upper limit beyond which further increase of compression pressure seems counterproductive. For inelastic bandages, this upper limit is around 30mmHg on the upper and around 50-60mmHg on the lower extremity[62].

This difference in optimal pressure range between upper and lower extremities seems to be caused by the different levels of filtration pressure in the capillaries which, in the upright position, is much higher in the leg than in the arm. Too high pressure may impede the lymphatic pump. Lymphatic congestion lymphoscintigraphy[63] showed reduced pressures generated by the lymphatic pump in patients with arm lymphoedema (24 + 19mmHg) compared to normal controls (39 + 14mmHg). This may explain the surprising result that inelastic bandages applied with a pressure under 30mmHg achieved more volume reduction than bandages with a pressure of more than 50mmHg[60].

These findings have practical implications concerning the time period when a bandage needs to be changed because of getting loose. If bandage changes are done twice daily, a low pressure bandage will be more effective than a bandage applied with high pressure. Outpatient bandage changes are usually performed in longer time intervals thus taking the rapid pressure fall into consideration, a higher initial pressure will provide longer periods in which an optimal pressure range will be delivered.

What are our compression tools?

A wide spectrum of different compression devices following different national regulations is available. Table 2 gives an overview, including some brand names as examples for specific products. While hosiery and compression devices are mentioned, discussion of these is out-with the scope of this document.

In a consensus document, the characteristics for a compression device have been outlined as the acronym of P-LA-C-E, where P= Pressure, LA= Layers. C= Components, E= Elastic property of the single component[17].

Pressure: corresponding to the dosage of treatment, it is the deciding parameter of compression and bandage application. It depends mainly on the manual force which is used to stretch the bandage during application and on the curvature of the limb segment. For the lower extremity the following pressure ranges were defined:

- mild (< 20mmHg)
- moderate (>20–40mmHg)
- strong (>40–60mmHg)
- very strong (> 60mmHg)

The only way to assess these pressures is to measure them by adequate instrumentation, recommended for training purposes and for trials, but not for everyday practice[64]. This classification differs from the compression classes given by the producers of hosiery, varying from country to country. The pressure stocking will depend on the elastic strength of the stocking and the relationship between the size of the extremity and the adequately prescribed stocking.

Layers: correspond to the amount of overlaps; thus, practically all bandages are multi-layer. A single compression sleeve has one layer, a double stocking has two.

Components: most modern bandages are composed of different components, such as padding material and various additional textiles. This is especially the case for the classical lymphoedema compression bandaging (LCB), which is actually a multi-component lymphatic bandage.

Elastic property: the elastic property of the textiles used influences the therapeutic index derived from the difference between efficacy and tolerability. Basically, this relationship corresponds to the difference between working pressure and resting pressure *(Figure 2)*. To achieve a high working pressure using an elastic, long-stretch bandage, the wrap would need to be applied with a high resting pressure, barely tolerable in the resting position. Inelastic,

Table 2: Methods of compression

Type	Examples	Application	Advantages	Disadvantages	Stiffness
Inelastic	Zinc paste (Unna)	Trained staff, may stay for some days	High working pressure, well tolerated during rest	Messy	Very high
Single component Short-stretch wrap	Double Comprilan®, Pütter®, Porelast®, Panelast® (adhesive), Actico® (cohesive)	Trained staff, may stay for some days	High working pressure, well tolerated during rest. Comprilan and Pütter are washable and resusable	Slippage Adhesive and cohesive materials not reusable	High
Multi component Inelastic*	Lymphsets*, Lymph kits*, Rosidal® sys, Coban® 2 and Coban® 2 Layer Lite (cohesive) Actico®+ Sofban® (cohesive)	Trained staff, may stay for some days	High working pressure, well tolerated during rest, Less slippage Non-adhesive, non-cohesive : Washable and reusable	Cohesive materials not reusable	High
Multi component Long-stretch	Four layer (Profore*)	Trained staff, may stay for some days	High working pressure, well tolerated during rest,	Not reusable, bulky and warm	High
Single component Long-stretch wrap Elastic	Ace™, SurePress®, Perfekta®, Dauerbinde®, Biflex® Thuasne	Easy application, needs to be removed over night	Self-application, restricted reusabilty	Low working pressure, not tolerated when applied with high pressure	Low
Compression stockings Elastic, round knitted	Variety of products in different compression classes Ready-made	Self-application	Patient can have showers, daily skin care, self-management	Low working pressure, difficult donning	Low
Ulcer stockings	Double stockings (ulcer kits)	Base layer stays over night and keeps ulcer-dressing in place. Second stocking during day-time	Patient can have showers, daily skin care, self-management	Difficult donning	Medium
Compression stockings Flat knitted*	Variety of products. Mainly custom-made, sometimes with zippers	Self-application	Shape distortion. Patient can have showers, daily skin care, self-management,	Thicker, difficult donning,	Medium
Velcro-devices (short-stretch)	CircAid® FarrowWrap	Self-application, Self-adjustable	Patient can have showers, daily skin care, self-management	Not appealing	Medium-high
Extremity pump	Variety of products in different versions	Self-application. Self-adjustable	Patient can have showers, daily skin care, self-management	Works when patient is resting for limited time. Adjunctive use	High

*Key: * preferred materials for lymphoedema management* short-stretch material offers a much broader therapeutic index exerting a well tolerable, low resting pressure and a high working pressure *(Figure 2)*.

By applying two or more layers of elastic material over each other the final bandage will change its elastic property, becoming getting more inelastic (stiff) due to the friction between the layers. Stiff bandages can also be achieved by adhesive (binding to the skin) or cohesive surfaces (sticking to itself). On the human extremity, stiffness may be defined as the increase of compression pressure due to an increase of the limb circumference following standing up from the lying position (static stiffness index) or during movement (dynamic stiffness index).

What are the characteristics of an ideal compression system?

The following requirements were defined for an ideal compression system in patients with leg ulcers *(Box 1)*[65].

Box 1: Requirements for an ideal compression system for patients with venous leg ulcers

- Proven clinical effectiveness
- Can provide and maintain clinically effective levels of compression for at least a week during walking/rest
- Enhances calf muscle pump function
- Non-allergic, easy to apply
- Conformable, comfortable (non-slip) and durable

NB. Most of the listed points are also features of the classical inelastic bandage for patients with chronic oedema/lymphoedema.

Why high stiffness devices in lymphoedema?

Although clear scientific evidence is lacking, there are some arguments from experimental studies to support the concept of using stiff material in the initial treatment phase of chronic oedema/lymphoedema, namely:

1. Inelastic, stiff bandages have a low, well tolerable resting pressure, even when initially applied very tightly, and a high working pressure. When a stiff bandage is strongly applied under high tension, exerting a pressure on the leg of for example, 60mmHg, oedema removal begins immediately and the pressure decreases very quickly into a range which will also be well tolerated during rest (for example, to 40mmHg). However, when the patient gets up there will be an immediate, steep increase of pressure which will counteract the increase of hydrostatic oedema (intelligent bandage). As described previously, the amount of pressure increase by standing up characterises the stiffness of the compression device.

   The pressure loss of such bandages is very fast (after 2 hours in leg lymphoedema >30%, in arm lymphoedema > 40%)[44]. Thus, such bandages should be reapplied when they become too loose to keep the levels of compression in an effective range.

2. Stiff bandages will not give way during exercise and will create a 'massaging effect' during muscle contractions *(Figure 2)*. Such pressure fluctuations are able to stimulate the rhythmic pulsations of lymph collectors provided these are still intact. Even if this is not the case as, for example, in severe obstructive lymphoedema, an increase of pulsating intra-lymphatic flow could be shown[11]. In addition, this massaging effect of stiff bandages during movement will lead to similar effects in the microcirculation and in the tissue as described with intermittent pressure pumps.

The ideal compression profile and the question of padding

One dogma of gradient compression suggests that the pressure over distal parts of the extremity has always to be higher than over proximal parts. For elastic compression stockings, a continuous pressure reduction from distal to proximal (degressive pressure profile) is postulated as an important quality criterion in manufacturers standards. However, this dogma has been challenged in respect of mobile, venous patients; a higher pressure over the calf results in a stronger blood expelling force of the muscle pump[66].

Lymphoedema patients show altered limb shapes and deformities due to a peculiar distribution of oedema, fat and fibrosclerotic tissue *(Figures 4 & 5)*. A common recommendation for bandaging such limbs is to change the contour of the limb into a cone by padding and applying a bandage under constant stretch. This relies on Laplace's law that the bandage pressure will automatically be higher over the distal smaller circumference than proximal. Reshaping the contour of the extremity may rather be achieved by moulding the bandage to the limb in an individual manner, trying to avoid too much padding, without trying to avoid too high proximal pressures.

Padding is often considered a safety feature recommended mainly to less experienced bandagers. Some experimental work has been carried out showing that padding is dissipating and reducing the pressure from areas which would need stronger compression, changes stiffness, makes bandages bulky and hot and frequently promotes slippage, depending on the material used[67,68]. When by using lymphoedema bandaging it should always be kept in mind that a bulk of padding may inhibit

Figure 4: Advanced limb distortion

Figure 5: Obesity associated with lymphoedema causing limb distortion

functionality and impede joint mobility. This is obviously the reason why in two recent studies[44,69], a two-component system and a Velcro band device respectively achieved more volume reduction compared to a conventional multi-component system in spite of comparable resting pressures.

Compression in immobile patients

Patients with restricted mobility, who are often overweight, and wheel-chair dependent, present a practical problem. Dependency will cause leg swelling which may turn into lymphoedema and patients will be unable to put on compression themselves.

Inelastic compression material is preferred in the context of DLT and works best in combination with exercises. With every extension of the limb due to muscle activity the non-yielding material will exert pressure peaks causing a massaging effect. As shown in figure 2, this massaging occurs even with minimal movement of the toes, more powerfully under inelastic compared to elastic material. In immobile patients the same effect can also be seen when toes or ankles are passively moved by a nurse, a physiotherapist or a relative of the patient. However, inelastic material does not work only in connection with movement. Such bandages, applied with high enough pressure by trained staff will lead to a fast reduction of leg-volume and will need to be changed initially in time intervals of twice or three times per week. Later, weekly bandage changes may be sufficient and the patient and family-members should be instructed to move, actively or passively, as much as possible. In addition pressure pumps may support this strategy[70]. This is certainly a more reasonable and effective management than applying elastic bandages or compression stockings every morning, often by home-nurses, based mainly on the misconception that inelastic material would works only in mobile patients.

General recommendations concerning compression therapy

Compression will always be the most important single component of DLT in treating patients with chronic oedema/lymphoedema. Some specific aspects are summarised below:

- chronic oedema and lymphoedema need continuous compression. When compression is discontinued, oedema will recur. This is also true after liposuction and most other surgical procedures
- while venous problems are associated with living in the upright position and compression in such patients is mainly needed during the daytime, lymphatic damage preferably requires compression day and night
- self-management is a goal based on important psychological and economic advantages. To this end, education of the patient underlining the importance of compression and movement (structured exercises) is essential
- the initial therapy phase should start by using compression which is adjusted to the underlying pathology and limb size and also to the local background concerning practical feasibility
- inelastic bandages applied by trained personnel should not impede joint movement and avoid slipping down. Renewal time needs to be adjusted to the amount of oedema reduction (pressure fall) and local facilities
- self-treatment could be promoted by using pumps, Velcro band devices and by fitting compression sleeves

- when no more oedema reduction can be achieved during this initial intensive therapy phase, compression needs to be continued using compression sleeves. These may need to be made-to-measure, especially in patients with gross deformations and preferably inelastic (flat knitted). Additional intermittent pneumatic compression or phases with short-stretch bandages may be useful especially when oedema reduction can not be sufficiently maintained
- compression should always be accompanied by the other components of DLT, especially exercise, to enhance functionality and the decongestive effects of compression, and skin care in order to prevent (recurrent) infections which will worsen lymphatic drainage

References

1. Földi M, Földi E, Kubik S. (2003) *Textbook of Lymphology.* Urban & Fischer, Elsevier, Munich
2. Browse N, Burnand KG, Mortimer P. (2003) *Diseases of the Lymphatics.* Arnold, London
3. Olszewski WL. (1991) *Lymph Stasis: Pathophysiology, Diagnosis and Treatment.* CRC Press, Boca Raton
4. Moffatt CJ, Franks PJ, Doherty DC, *et al.* (2003) Lymphoedema: an underestimated health problem. *QJM.* 96 (10): 731-738
5. Bunke N, Brown K, Bergan J. (2009) Phlebolymphemeda: usually unrecognized, often poorly treated. *Perspect Vasc Surg Endovasc Ther.* 21 (2): 65-8
6. Mortimer PS. (1995) Evaluation of lymphatic function: abnormal lymph drainage in venous disease. *Int Angiol.* 14 (3) (Suppl 1): 32-5
7. Szczesny G, Olszewski WL. (2003)The pathomechanism of posttraumatic edema of the lower limbs: II--Changes in the lymphatic system. *J Trauma.* 55 (2): 350-4
8. Casley-Smith JR, Casley-Smith JR. (1986) *High-Protein Oedemas and the Benzo-Pyrones.* JB Lippincott, Sydney
9. Olszewski WL. (2003) Pathophysiological aspects of lymphedema of human limbs: I. Lymph protein composition. *Lymphat Res Biol.* 1 (3): 235-43
10. Franzeck UK, Spiegel I, Fischer M, *et al* (1997) Combined physical therapy for lymphedema evaluated by fluorescence microlymphography and lymph capillary pressure measurements. *J Vasc Res.* 34 (4): 306-11
11. Olszewski WL. (2008) Contractility patterns of human leg lymphatics in various stages of obstructive lymphedema. *Ann N Y Acad Sci.* 1131: 110-8
12. Starling EH. (1896) On the absorption of fluids from the connective tissue spaces. *J Physiol.* (London) 19 (312)
13. Levick JR, Michel CC. (2010) Microvascular fluid exchange and the revised Starling principle. *Cardiovasc Res.* 87 (2): 198-210
14. Stranden E. (2011) Edema in venous insufficiency. *Phlebolymphology* 8: 3-14
15. Földi E, Jünger M, Partsch H. (2005) The science of lymphoedema bandaging. *EWMA Focus Document: Lymphoedema bandaging in practice.* MEP Ltd, London
16. Partsch B, Partsch H. (2005) Calf compression pressure required to achieve venous closure from supine to standing positions. *J Vasc Surg.* 42 (4): 734-8
17. Partsch H, Clark M, Mosti G, *et al.* (2008) Classification of compression bandages: practical aspects. *Dermatol Surg.* 34 (5): 600-9
18. Mosti G, Mattaliano V, Partsch H. (2008) Influence of different materials in multicomponent bandages on pressure and stiffness of the final bandage. *Dermatol Surg.* 34 (5): 631-9
19. Mosti G, Iabichella ML, Partsch H. (2012) Compression therapy in mixed ulcers increases venous output and arterial perfusion. *J Vasc Surg.* 55 (1): 122-8
20. Mayrovitz HN, Macdonald JM. (2010) Medical compression: effects on pulsatile leg blood flow. *Int Angiol.* 29 (5): 436-41
21. Klyscz T, Galler S, Steins A, *et al.* (1997) The effect of compression therapy on the microcirculation of the skin in patients with chronic venous insufficiency (CVI). *Hautarzt.* 48 (11): 806-11
22. Bollinger A, Fagrell B. (1990) *Clinical capillaroscopy.* Hofgrebe & Huber, Toronto
23. Abu-Own A, Shami SK, Chittenden SJ, *et al.* (1994) Microangiopathy of the skin and the effect of leg compression in patients with chronic venous insufficiency. *J Vasc Surg.* 9 (6): 1074-83
24. Coleridge-Smith PD. (2002) Deleterious effects of white cells in the course of skin damage in CVI. *Int Angiol.* 21 (2 Suppl 1): 26-32
25. Lentner A, Wienert V. (1996) Influence of medical compression stockings on venolymphatic drainage in phlebologically healthy test persons and patients with chronic venous insufficiency. *Int J Microcirc Clin Exp.* 16 (6): 320-4
26. Beidler SK, Douillet CD, Berndt DF, *et al.* (2009) Inflammatory cytokine levels in chronic venous insufficiency ulcer tissue before and after compression therapy. *J Vasc Surg.* 49 (4): 1013-20
27. Beidler SK, Douillet CD, Berndt DF, *et al.* (2008) Multiplexed analysis of matrix metalloproteinases in leg ulcer tissue of patients with chronic venous insufficiency before and after compression therapy. *Wound Repair Regen.* 16 (5): 642-8
28. Chen AH, Frangos SG, Kilaru S, *et al.* (2001) Intermittent pneumatic compression devices; physiological mechanisms of action. *Eur J Vasc Endovasc Surg.* 21 (5): 383-92
29. Vissing SF, Secher NH, Victor RG. (1997) Mechanisms of cutaneous vasoconstriction during upright posture. *Acta Physiol Scand.* 159 (2): 131-8
30. Husmann M, Willenberg T, Keo HH, *et al.* (2008) Integrity of venoarteriolar reflex determines level of microvascular skin flow enhancement with intermittent pneumatic compression. *J Vasc Surg.* 48 (6): 1509-13
31. Svedman C, Cherry GW, Ryan TJ. (1998) The veno-arteriolar reflex in venous leg ulcer patients studied by laser Doppler imaging. *Acta Derm Venereol.* 78 (4): 258-61
32. van Geest AJ, Veraart JC, Nelemans P, *et al.* (2000) The effect of medical elastic compression stockings with different slope values on edema; measurements underneath three different types of stockings. *Dermatol Surg.* 26 (3): 244-7
33. Partsch H. (2003) Understanding the pathophysiological effects of compression. In: *EWMA Position Document: Understanding Compression Therapy.* MEP Ltd, London
34. Adams K, Rasmussen J, Darne C, *et al.* (2010) Direct evidence of lymphatic function improvement after advanced pneumatic compression device treatment of lymphoedema. *Biomed Opt Express.* 1 (1): 114–125
35. Haid H, Lofferer O, Mostbeck A, *et al.* (1968) Lymph kinetics in the postthrombotic syndrome under compression bandages. *Med Klin.* 63 (19): 754-7

36. Bräutigam P, Földi E, Schaiper I, *et al.* (1998) Analysis of lymphatic drainage in various forms of leg edema using two compartment lymphoscintigraphy. *Lymphology.* 31 (2): 43-55
37. Olszewski WL, Jain P, Ambujam G, *et al.* (2011) Tissue fluid pressure and flow during pneumatic compression in lymphedema of lower limbs. *Lymphat Res Biol.* 9 (2): 77-83
38. Olszewski WL, Cwikla J, Zaleska M, *et al.* (2011) Pathways of lymph and tissue fluid flow during intermittent pneumatic massage of lower limbs with obstructive lymphedema. *Lymphology.* 44 (2): 54-64
39. Földi E, Sauerwald A, Hennig B. (2000) Effect of complex decongestive physiotherapy on gene expression for the inflammatory response in peripheral lymphedema. *Lymphology.* 33 (1): 19-23
40. Vandongen YK, Stacey MC. (2000) Graduated compression elastic stockings reduce lipodermatosclerosis and ulcer recurrence. *Phlebolog.* 15: 33-7
41. Partsch H, Stöberl C, Urbanek A, *et al.* (1998) Clinical use of indirect lymphography in different forms of leg edema. *Lymphology.* 21 (3): 152-60
42. Partsch H, Mosti G, Mosti F. (2010) Narrowing of leg veins under compression demonstrated by magnetic resonance imaging (MRI). *Int Angiol.* 29 (5): 408-10
43. Damstra RJ, Partsch H. (2009) Compression therapy in breast cancer-related lymphedema: A randomized, controlled comparative study of relation between volume and interface pressure changes. *J Vasc Surg.* 49 (5): 1256-63
44. Lamprou DA, Damstra RJ, Partsch H. (2011) Prospective, randomized, controlled trial comparing a new two-component compression system with inelastic multicomponent compression bandages in the treatment of leg lymphedema. *Dermatol Surg.* 37 (7): 985-91
45. Partsch H, Stout N, Forner-Cordero I, *et al.* (2010) Clinical trials needed to evaluate compression therapy in breast cancer related lymphedema (BCRL). Proposals from an expert group. *Int Angiol.* 29 (5): 442-53
46. Badger C, Preston N, Seers K, *et al.* (2004) Physical therapies for reducing and controlling lymphoedema of the limbs. *Cochrane Database Syst Rev.* 18 (4): CD003141. Review
47. Badger CM, Peacock JL, Mortimer PS. (2000) 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.* 88 (12): 2832-2837
48. Bertelli G, Venturini M, Forno G, *et al.* (1991) Conservative treatment of postmastectomy lymphedema: a controlled, randomized trial. *Ann Oncol.* 2: 575–578.
49. Johansson K, Lie E, Ekdahl C, *et al.* (1998) A randomized study comparing manual lymph drainage with sequential pneumatic compression for treatment of postoperative arm lymphedema. *Lymphology.* 31: 56–64
50. Radakovic N, Popovic-Petrovic S, Vranjes N, *et al.* (2010) A comparative pilot study of the treatment of arm lymphedema by manual drainage and sequential external pneumatic compression (SEPC) after mastectomy. *Arch Oncol.* 6: 177–178
51. Andersen L, Hojris I, Erlandsen M, *et al.* (2000) Treatment of breast-cancer-related lymphedema with or without manual lymphatic drainage–a randomized study. *Acta Oncol.* 39: 399–405
52. McNeely ML, Magee D, Lees A, *et al.* (2004) The Addition of Manual Lymph Drainage to Compression Therapy For Breast Cancer Related Lymphedema: a Randomized Controlled Trial. *Breast Cancer Res Treat.* 86: 95-106
53. Szuba A, Achalu R, Rockson SG (2000) Decongestive lymphatic therapy for patients with breast carcinoma-associated lymphedema: a randomised prospective study of a role for adjunctive intermittent pneumatic compression. *Cancer.* 95 (11): 2260-7
54. Didem K, Ufuk YS, Serdar S, *et al* (2005) The comparison of two different physiotherapy methods in treatment of lymphedema after breast surgery. *Breast Cancer Res Treatment.* 93: 49–54
55. Wilburn O, Wilburn P, Rockson SG (2006) A pilot, prospective evaluation of a novel alternative for maintenance therapy of breast cancer-associated lymphedema. *BMC Cancer.* doi: 10. 1186/1471-2407-6-84
56. Irdesel J, Kahraman CS. (2007) Effectiveness of exercise and compression garments in the treatment of breast cancer related lymphedema. *Turkiye Fiziksel Tip ve Rehabilitasyon Dergisi.* 53: 16–21
57. Tsai HJ, Hung HC, Yang JL, *et al.* (2009) Could Kinesio tape replace the bandage in decongestive lymphatic therapy for breast-cancer-related lymphedema? A pilot study. *Support Care Cancer.* 17: 1353–1360
58. Partsch H, Stout N, Forner-Cordero I, *et al.* (2010) Clinical trials needed to evaluate compression therapy in breast cancer related lymphedema (BCRL). Proposals from an expert group. *Int Angiol.* 29 (5): 442-53
59. International Society of Lymphology. (2003) The diagnosis and treatment of peripheral lymphedema. Consensus document of the International Society of Lymphology. *Lymphology.* 36 (2): 84-91
60. Damstra RJ, Partsch H. (2009) Compression therapy in breast cancer-related lymphedema: A randomized, controlled comparative study of relation between volume and interface pressure changes. *J Vasc Surg.* 49 (5): 1256-63
61. Mosti G, Picerni P, Partsch H. (2011) Compression stockings with moderate pressure are able to reduce chronic leg oedema. *Phlebology.* [Epub ahead of print]
62. Partsch H, Damstra RJ, Mosti G. (2011) Dose finding for an optimal compression pressure to reduce chronic edema of the extremities. *Int Angiol.* 30 (6): 527-33
63. Modi S, Stanton AW, Svensson WE, *et al.* (2007) Human lymphatic pumping measured in healthy and lymphoedematous arms by lymphatic congestion lymphoscintigraphy. *J Physiol.* 583. (Pt 1): 271-85
64. Partsch H, Clark M, Bassez S, *et al.* (2006) Measurement of lower leg compression in vivo: recommendations for the performance of measurements of interface pressure and stiffness: consensus statement. *Dermatol Surg.* 32 (2): 224-32
65. Marston W, Vowden K. (2003) Compresssion therapy: a guide to safe practice. *EWMA Position Document: Understanding compression.* MEP Ltd, London
66. Mosti G, Partsch H. (2011) Compression stockings with a negative pressure gradient have a more pronounced effect on venous pumping function than graduated elastic compression stockings. *Eur J Vasc Endovasc Surg.* 42 (2): 261-6
67. Schuren J. (2011) Compression unravelled. Doctoral Thesis, Erasmus University Rotterdam
68. Mosti G, Mattaliano V, Partsch H. (2008) Influence of different materials in multicomponent bandages on pressure and stiffness of the final bandage. *Dermatol Surg.* 34 (5): 631-9
69. Damstra R, Partsch H. (2012) Prospective, Randomized Controlled Trial Comparing the Effectiveness of adjustable compression Velcro-wraps versus Inelastic Multilayer Compression Bandages in the initial Treatment of Leg Lymphedema. *J Vasc Surg.* In print
70. Partsch H. (2008) Intermittent pneumatic compression in immobile patients. *Int Wound J.* 5 (3): 389-97

CHAPTER 3
Optimising compression bandaging

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Introduction

At present, complete decongestive therapy (CDT), a combination of manual lymphatic drainage, functional exercises, skin care, and compression, has been shown to be effective in lymphoedema care. The mechanisms of action of each individual component remain poorly understood and still many controversies exist. In the introduction of the European Wound Management Association (EWMA) focus document on lymphoedema bandaging, Moffatt[1] states that much of the evidence on how compression works is based on research into venous disease, which has been extrapolated to lymphoedema. In addition, she concludes that many studies report on the use of decongestive lymphatic therapy as a whole and it is therefore difficult to determine the precise role played by compression. In the same document, Földi *et al*[2] conclude that although CDT has been used for over a century and is clearly successful, the mechanisms of action of each component remain poorly understood. Based on a systematic review of the most common conservative therapy, Mosely *et al*[3] conclude that despite the range of positive outcomes they identified, the evidence to support them is in some instances poor and that there is still a need for large scale, high level clinical trials in this area.

Ko *et al*[4] performed an analysis of 290 patients treated with a well-defined CDT-protocol and suggested that because of the excellent and sustained results provided by CDT, pneumatic pumps or surgical treatments should no longer be the primary therapy recommended for chronic lymphoedema. Olszewski[5] found that in healthy limbs with normal lymphatics, active movements of the foot and leg do not significantly increase the lymph mean systolic pressures and flow. However, when lymphoedema is present, leg muscle contractions either stimulate lymphatic contractions, subsequently increasing lymph flow, or generate intra-lymphatic pressures, propelling lymph. The author showed that bandaging with pressures around 40mmHg supported the muscle contractions to effectively propel lymph. Cheville *et al*[6] report that remedial exercises, which are always performed with some type of external compression, influence lymphatic physiology and facilitate lymphoedema volume reduction by exerting local and systemic effects that stimulate the intrinsic contractility of the lymph transport vessels. Functional activities can release fibrosis, normalise biomechanics, enhance posture, and facilitate lymph flow. Therefore, range of motion should be performed for all joints within and proximal to the territory affected by lymphoedema. The importance of compression combined with functional activities is obvious. Compression therapy should be applied in such a way that functional activities are not limited by its use.

This chapter reviews some of the physics of compression therapy including Laplace's and Pascal's laws and the use of padding. In addition, it highlights the importance of function and provides evidence supporting joint mobility to optimise compression therapy. It should be noted that the research in this chapter is based on compression bandaging for venous leg ulceration.

Laplace's law

The pressure generated by a bandage application is a function of the tension in the fabric and the radius of curvature of the limb to which it is applied. The relationship between these factors is also governed by Laplace's law, as the sub-bandage pressure is directly proportional to bandage tension, but inversely proportional to the radius of curvature of the limb to which it is applied[7]. This relation is expressed in the equation: $P=T/R$, where P is the sub-bandage pressure, T is the tension with which the bandage is applied and R is the radius of the curvature to which the bandage is applied. However, while Laplace's original formula provided a mechanistic view of the pressures exerted on curved surfaces, it did not take into account the adaptations that can occur in living organisms, for example, the human leg, which is neither solid nor has a constant curved structure[8]. Therefore, the direct relationships that occur in solid objects may not apply to human bodies with deformable or irregular surfaces[9]. To include the importance of bandage width and the number of layers applied, Thomas[7] modified Laplace's law in such a way that it might be used in clinical practice. The modified equation *(Box 1)*, often referred to as Laplace's law, is frequently used to calculate the sub-bandage pressures of compression systems:

Box 1: Modified Laplace's law

pressure in mmHg = (tension in KgF x number of layers x 4620) / (circumference in cm x bandage width in cm)

NB: KgF = Kilogram of force

There is a widespread belief that most of the compression systems currently on the market provide graduated compression, with a pressure of 35-40mmHg at the ankle, dropping off to about 15mmHg at the widest circumference of the calf. The original Charing Cross four-layer compression system was developed to apply 40mmHg of pressure at the ankle, graduating to 17mmHg at the knee[10]. Blair *et al*[11] state that because of the increased radius from ankle to calf, graduated compression will be applied automatically, providing the same tension and overlap are used. They add that mistakes in the tension applied in any one layer of the four-layer system will tend to be averaged out. De Bruyne *et al*[12] present a device to measure the pressure exerted by an elastic stocking without upsetting the original application. The method reveals that a cross-sectional pressure value, which is the result of the Thomas equation, is not a realistic value due to variation in curvature. The authors demonstrated that the radial pressure is only exerted on convex surfaces and the tested stocking cannot exert pressure if the surface is plane or concave. Much of the literature supports the 40–17 mmHg compression value as the ideal in healing venous leg ulcers[13] and many practitioners take these values for granted and sub-bandage pressure measurements are rarely performed.

Schuren *et al*[14] studied the applicability of Laplace's law on the use of compression bandaging materials with measurements from 744 compression bandages applied to an artificial leg by experts in compression bandaging. The authors revealed that the theoretical pressure values calculated by the modified Laplace's law equation did not predict the values found when compression bandages were applied by experts. The data clearly indicate that *in vivo* pressure values calculated by using Laplace's law should be interpreted with care. In addition, none of the compression systems tested provided dependable graduated compression on the artificial legs used in the studies. It was concluded that the widespread belief that correctly applied compression systems provide pressure values graduating from 40mmHg at the ankle to 17mmHg below the knee, is based solely on theoretical mathematical equations and is not supported by the results of the experimental studies in this chapter. Thomas[7] explains that the application of two layers of a bandage, applied with constant tension, will double the number of yarns over any particular point on the surface of the leg and thus, for all practical purposes, double the pressure applied. For this reason the number of layers of bandage applied must be considered when calculating sub-bandage pressure.

Schuren[15] performed pressure measurements in complete controlled applications and revealed that this is not the case *(Figures 1, 2 & 3)*.

Figure 1: Theoretical and measured pressure values of Coban® 2 Layer

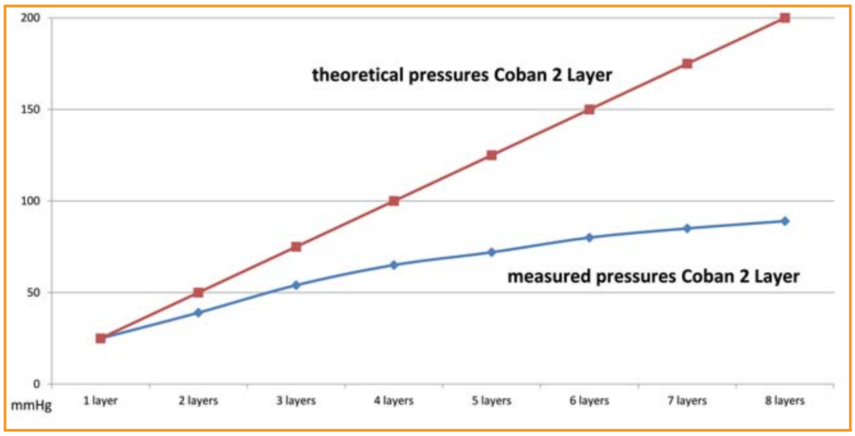
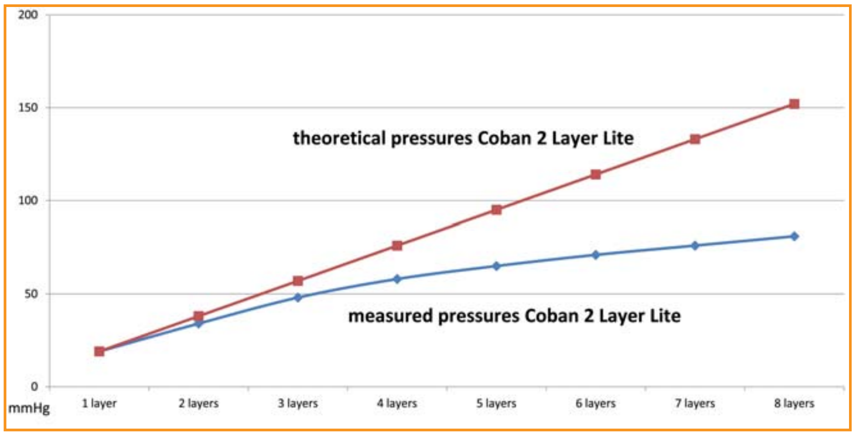


Figure 2: Theoretical and measured pressure values of Coban® 2 Layer Lite



In these graphs, the solid lines represent the measured values, the dotted lines are the calculations based on the Thomas equation[7]. The lines of the theoretical and actual values have only a common starting point with the values deviating from the second layer.

To study material stiffness, Schuren[16] developed a method for a completely controlled application and stiffness recording on test cylinders. The stiffness recorded in this way is referred to as Strain Index[16]. The most important finding in this study was that, with all bandages being applied at full stretch, only a small increase in the observed index could be observed between layer 1 and layer 2, after which the indices stay more or less stable by adding additional layers *(Figure 4)*.

In clinical practice, especially in lymphoedema bandaging, additional overlapping layers are frequently applied to produce the desired pressure characteristics[17]. Looking at the measured stiffness, it is obvious that the effectiveness of a properly applied compression system is not determined by the number of layers but by the fact that these layers are applied at full stretch.

Figure 3: Theoretical and measured pressure values of Rosidal K®

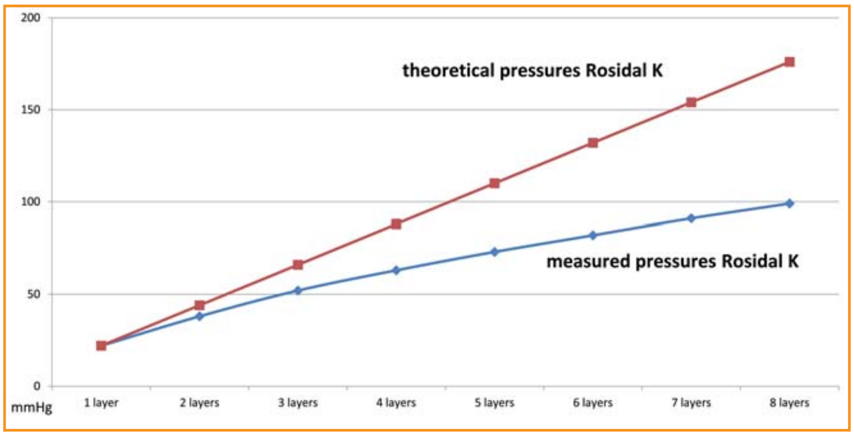
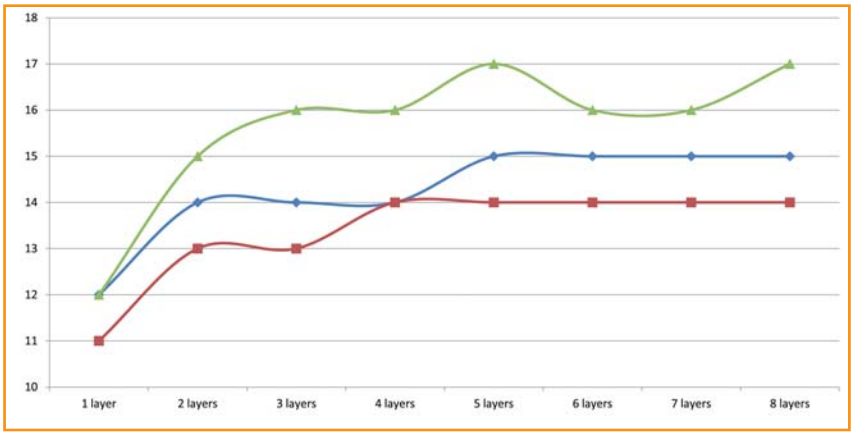


Figure 4: Stiffness (strain indices) for the three materials under investigation

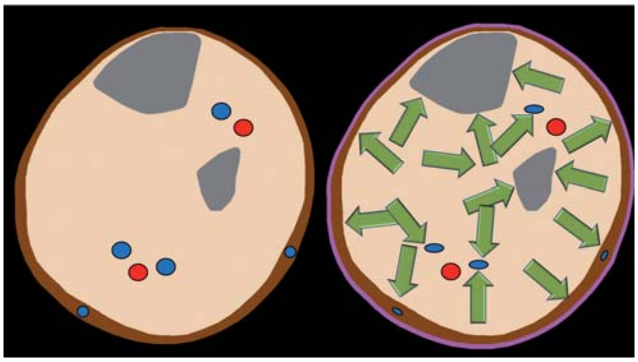


Pascal's law

Pascal's law states that, when there is an increase in pressure at any point in a contained fluid, there is an equal increase at every other point in the container. Pascal's principle means that an incompressible fluid transmits applied pressure. It can be demonstrated by making a few similar openings in a closed toothpaste tube. If pressure is applied at any point on the tube, the toothpaste will come out evenly from all the holes.

Schuren *et al*[18] demonstrated that Pascal's law more accurately predicts the dynamics of compression therapy as the soft tissues of the leg act similarly to fluid when contained in a compression bandage, and will transmit the applied forces *(Figure 5)* equally, provided that the applied compression system is not stretchable.

Figure 5



Left: cross section of the lower leg; right: when muscle activity creates pressure within the compressed leg, then according to Pascal's law, the pressure will be transmitted evenly within the compressed area

The importance of function

There is a strong relation between venous return from the leg and functional activities. It is a well-known phenomenon that muscular contractions are of crucial importance for promoting venous return to the heart. This is particularly the case in the dependent leg or in the leg of an upright individual, where muscle activities prevent pooling of blood in the venous system. Function is of utmost importance for a proper circulation in the leg. The importance of active movements was demonstrated by Sochart *et al*[19], who showed that active combined movements of the ankle joint produced higher peak and mean velocities of blood flow than passive ones. Lentner *et al*[20] demonstrated that ankle movement restriction might be exacerbated by multi-layer compression therapy. Box 2 outlines the deficiencies with current compression bandaging systems as identified by Moffatt *et al*[21].

All of these shortcomings negatively impact normal functional activities of patients. The authors studied slippage and physical symptoms and activities of daily living in a randomised crossover trial comparing Profore, a four-layer system with a long history of use in compression therapy to Coban® 2 Layer, a new two-layer system. The authors found significantly less bandage slippage in the Coban® 2 Layer group as well as a significantly greater improvement in the health-related quality of life score, especially in the domain that focused on daily functioning and comfort. The immobilising effects of compression bandaging have not been studied before.

Box 2: Deficiencies in bandaging systems

- Inconsistency in application techniques resulting in inconsistent pressures
- Bulkiness, which can impede wearing of normal footwear
- Bandage slippage and bunching

Schuren[22] studied the effect of five weeks of voluntary immobilisation of the ankle joint in a below-knee walking cast on muscle function in the lower leg and the time needed to normalise eventual effects after removal. While casted, the healthy subjects were allowed full weight bearing and function. It was found that immobilisation by itself did not result in a decline in muscle volume and only resulted in approximately 10% reduction of performance and ankle function, which resolved in 1-2 weeks. Probably the most important explanation for this observation is that full weight bearing and function was allowed during the period of immobilisation. It may be assumed that if the effects of wearing a cast have only a minimal effect, the effects of wearing a compression bandaging system will be at least similar, provided that the system allows normal functional activities. There is a widespread belief that long-term compression reduces muscle volume and joint stiffness; in reality, inactivity is the reason.

It can be concluded that the importance of maintaining normal function should not be underestimated when a compression system is applied, especially when the patient population requiring compression therapy is very vulnerable to developing the detrimental effects of immobility. In 1958, Rivlin stated that bandaging alone will not heal many ulcers but ambulation will do so, provided the patient can walk in comfort[23]. The same can be said when bandaging is used for patients with lymphoedema as leg muscle contractions effectively propel lymph[5].

The use of padding materials

When a cast is applied for a fracture, padding materials are applied for two reasons: to protect bony prominences and to accommodate post-traumatic swelling. With the available synthetic padding materials, it is possible to apply smooth and wrinkle-free padding. However, a critical look at the surface of carefully applied padding shows that there is a certain degree of irregularity. If a plaster-of-Paris or a rigid synthetic cast is applied over this padding and it is moulded to the anatomy, it is impossible to detect this irregularity from the outside of the application. This means that the moulding of the cast results in an unequal internal pressure. If this moulding is done in areas with very superficial vessels like the dorsum of the hand, one can imagine what the effect of this unequal internal pressure will be on the venous backflow and the development of finger oedema. For many reasons, compression therapy for chronic venous ulceration can be compared to cast treatment for fractures. Maintaining or improving both circulation and functional activities are common objectives. Historically, and similar to the application of plaster-of-Paris, the use of padding materials has not been common practice for compression therapy. It was only in the late 1980's, when the 4-layer bandage was developed, that padding materials were introduced to mitigate single component application errors[11,24].

White *et al*[25] studied whether any measurable advantages could be identified if casts applied without padding materials were compared to casts where routinely padding materials were used. It was found that functional activities in the unpadded casts showed significantly higher pressure peaks because of functional activities than the padded casts, which leads to the conclusion that venous return is significantly better supported when no padding is used. Schuren[26] measured the effects of padding materials under compression bandages applied to irregularly shape artificial legs. An artificial leg was developed with narrowed area around and above the ankle as is often seen with lipodermatosclerosis *(Figure 6, left leg)*. Six PicoPress® pressure sensors were positioned in such a way that a pressure profile could be created of the narrowed area of the leg. The sensors were covered with a loose stockinet to avoid sensor movement during subsequent bandage applications.

For the first application, the narrowed area was reshaped with 3M™ synthetic cast padding, followed by two layers of circularly applied padding and covered with Rosidal K®, applied at full stretch with circular windings with a 50% overlap *(Figure 7)*.

Filling the gap with padding and an additional two circular layers of padding prevents the short stretch bandage from adding any pressure to sensor 4, as can be seen in figure 8. The pressure on sensor 4 provided by the padding, represented by the blue dotted line is nearly the same as the pressure provided by the additional layers of short-stretch material, represented by the orange line. Also, the sensors 3 and 5 show a significant drop after the completed application.

Next, Coban® 2 Layer was applied at full stretch, covering the area as anatomically as possible *(Figure 9)*. The pressure profile of the Coban® 2 Layer application without reshaping is represented by the purple line in figure 8. The higher pressure on the forefoot is still observed. The overall pressure profile reveals an evenly distributed pressure.

Another limb deformity that is sometimes seen in patients with severe lymphoedema, is a skin fold or apron. Often this serious distortion is re-contoured by using padding materials. To study the effects of the use of padding materials to fill cavities on sub-bandage pressures, an artificial leg was developed with a large skin fold above the ankle joint *(Figure 6, right leg)*. Five PicoPress® pressure sensors were positioned in such a way that a pressure profile could be created of the area around the skin fold. The sensors were covered with a loose stockinet to avoid sensor movement during subsequent bandage applications.

For the first application on this leg, the skin fold was filled with 3M™ synthetic cast padding, followed by two layers of circularly applied padding and compressed with Rosidal K®, applied at full stretch with figure-of-eight winding *(Figure 10)*.

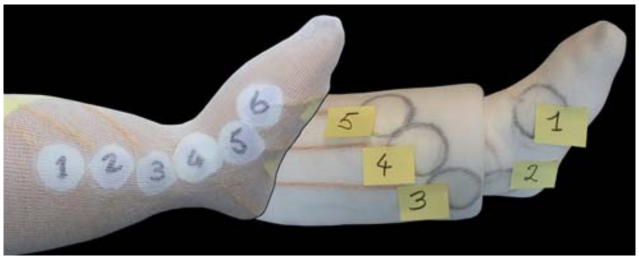
This technique prevents the short-stretch bandage from adding any pressure to sensor 2. As can be seen in figure 11, in the skin fold, the pressure provided by the padding, represented by the blue dotted line, is the same as the pressure provided by the additional layers of short stretch material represented by the orange line. Also, the surrounding sensors 1 and 3 are affected by the extra layers of padding used for filling the skin fold and show a pressure drop.

Next, the Coban® 2 Layer system was applied at full stretch, covering the fold as anatomically as possible without the use of additional padding *(Figure 12)*.

The pressure profile of the Coban® 2 Layer application is represented by the purple line in figure 11. There is still a pressure drop in sensor 2 but the overall profile reveals a more evenly distributed pressure.

The above studies on the artificial legs clearly demonstrate that padding materials have a dramatic effect on an even distribution of sub-bandage pressures, especially if they are used to «flatten» or «fill» irregularly shaped legs. These effects will be similar to what can be observed on patients' legs. According to Pascal's law, the uneven pressure profile created by re-contouring the leg, results in a reduced control of the forces that are built up

Figure 6: Two irregularly shaped artificial legs



Left; a leg with a narrowed area around and above the ankle, right; a leg with a skin fold

Figure 7: The reshaped narrowed area

The entire area covered with two layers of padding; Rosidal K, applied at full stretch

Figure 8: Pressure profile of the materials under investigation on the leg with the narrowed area around the ankle joint

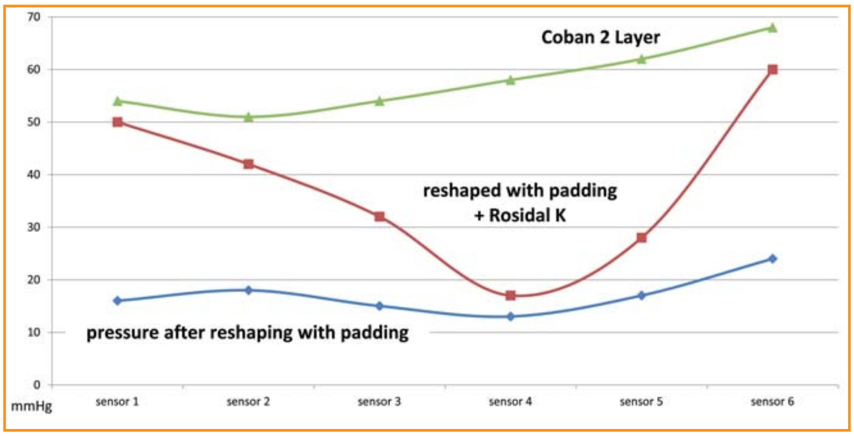


Figure 9: The application of the two layers of the Coban® 2

Pressure profile of the materials under investigation on the leg with the narrowed area around the ankle joint in the leg during functional activities and required to effective propel lymph[5].

The overall objective of compression therapy is to improve the venous return by supporting the calf muscle pump. It is well-documented that systems with a high stiffness provide a better support[27]. Most commercially available compression systems have some kind of padding material included; yet the amount of padding that will be used depends on the person that applies the system. This means that there may be quite some variation in individual applications. To study the effects of the use of padding materials on sub-bandage pressure and system stiffness in a completely controlled manner, a test method described by Schuren[16] was used. Ten poly-oxymethylene test cylinders, five with a radius of 4cm, the other five with a radius of 5cm, were wrapped with two layers of Rosidal K®, a short-stretch bandage by a specially designed automated roll-winder at full stretch without padding and subsequently with 1, 2, 3, 4 and 5 layers of padding. Immediately after each application, the pressure was recorded with a PicoPress® measuring device. The mean values of the pressure measurements are visualised in figure 13. The mean values of the stiffness measurements are presented figure 14.

This study reveals that padding not only has an effect on the resting pressure but also on the stiffness of an applied system directly affecting the final effectiveness of compression therapy.

Improving joint mobility, comfort and effectiveness

Inappropriate bandage selection and poor application are probably the commonest reported clinical problems associated with concordance[28]. Concordance with compression therapy remains poorly understood. There is currently no conclusive evidence as to which methods are most effective in improving concordance, but likely approaches include educational, behavioural and affective components[29]. In spite of these concerns, compression therapy has been proven to be an effective method to reduce oedema.

In many educational tools, bandaging methods are explained in detail[30,31]. In the majority of these tools, techniques are suggested that require large amounts of a variety of materials, resulting in bulky applications. The left picture in figure 15, taken from the Lymphoedema Framework 2006 consensus document[30] shows a partially bandaged hand. It is easy to imagine that with the application of so many layers, the functional properties of the hand are significantly reduced. As was shown, padding materials have a detrimental effect on the effectiveness of compression

Figure 10: The skin fold flattened with padding

Two layers of padding; Rosidal K applied at full stretch with figure-of-eight winding

Figure 11: Pressure profile of the materials under investigation on the artificial leg with the skinfold

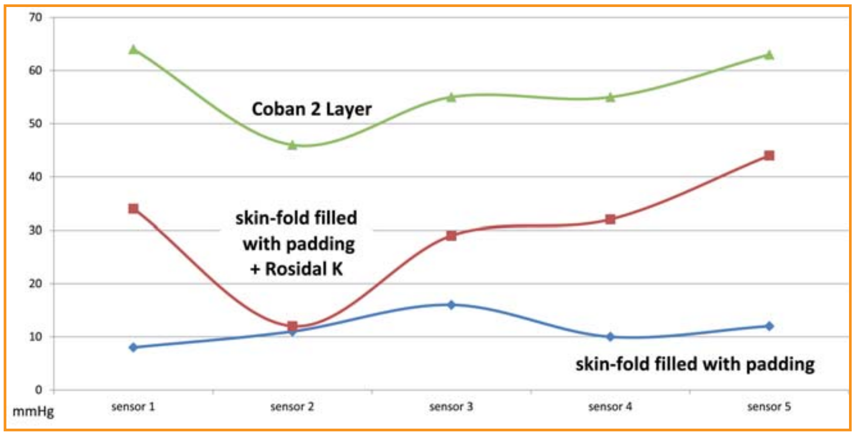


Figure 12: The application of the two layers of the Coban® 2 Layer application

therapy. Another disadvantage of padding materials is that they produce bulky applications. The right picture in figure 15 shows a hand that is bandaged with Coban® 2 Layer Lite, a material with an excellent stiffness when applied at full stretch. The most important advantage of this thin and comfortable application is that it allows a full range of motion.

Morgan *et al*[32] evaluated the experience of lymphoedema patients with the new 2-layer system and found that besides a swelling reduction for the majority of patients, the dominant advantages of this system over others, in the extensive experience of the participants, were its ease of application, its lightness, neatness, flexibility and ability to facilitate mobility. Moffatt *et al*[33] investigated the application frequency of the system and

Figure 13: Pressure measurements with different layers of padding

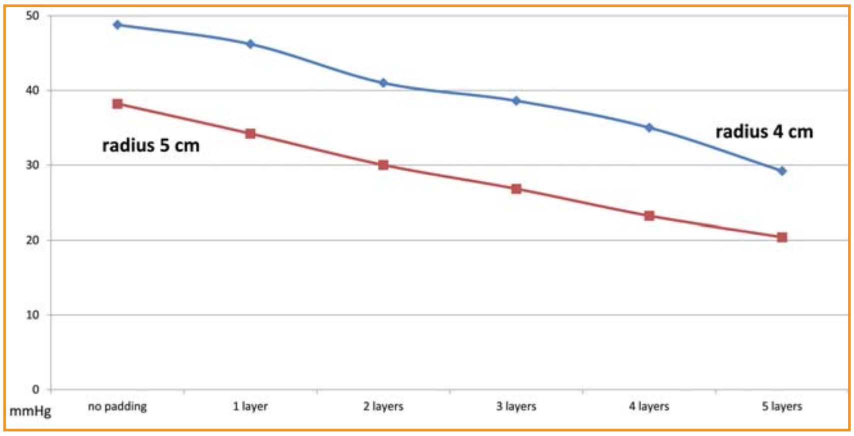


Figure 14: Stiffness with different layers of padding

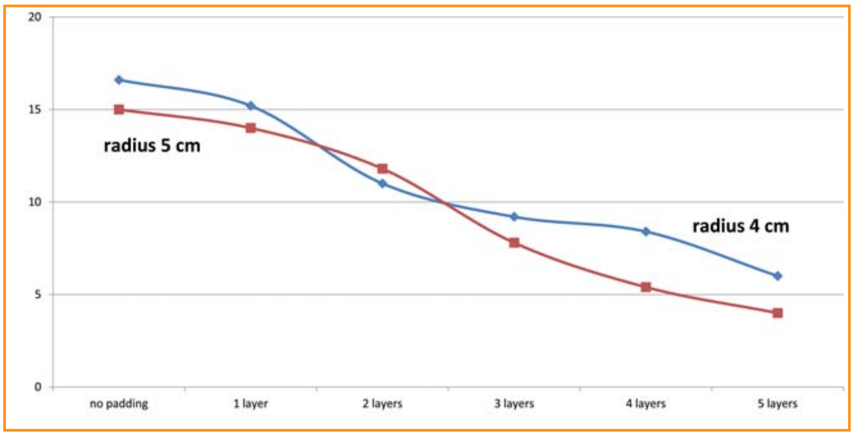


Figure 15: Two methods of hand application with the fingers included

although the results need to be substantiated by an appropriately powered randomised controlled trial, the authors found that the new system applied twice weekly demonstrated a high rate of volume reduction and a good safety profile. Oedema reduction was still effective with 4 days between bandage changes, which allows a constant therapeutic effect in routine practice. This should give the patient a high degree of independence and mobility.

Marston *et al*[34] describe the ideal compression therapy system as one that among other features, provides and maintains clinically effective levels of compression for at least one week during walking and at rest. Although not mentioned in the description, avoiding slippage is an essential part of fulfilling this crucial feature. Morgan *et al* explored the professional challenges of treating patients with complex/severe forms of chronic oedema/lymphoedema with compression therapy. Four focus groups were held, two in the UK and two in Canada, to examine the challenges faced by practitioners in their everyday practice[35]. The authors conclude their findings with the statement that now, more than ever, there is a need for cost-effective, time-efficient, compression bandaging systems that are light, flexible and can remain in situ for longer without slippage or loss of pressure to make a major contribution to meeting the challenges of contemporary lymphoedema practice. In a larger randomised cross-over trial comparing Profore and Coban® 2, Moffatt *et al*[21] found a significant difference in slippage in favour of Coban® 2 at days 3-7 and hypothesised that it is possible that the decreased slippage observed with the two-layer system translated into improved comfort to the patient because the health-related quality of life assessments observed during the study period revealed that both compression systems showed improved scores, but the improvement was significantly greater for the Coban® 2 than for Profore®. Further research is required in this area to support eventual conclusions.

Another question that needs to be answered is how much pressure is needed. Lamprou *et al*[36] conclude that the two-component system provides greater sub-bandage pressure for every centimeter of circumference than conventional short-stretch bandages and that this property potentially enhances the efficiency of long-term compression therapy during the conventional treatment of lymphoedema. For treatment of arm lymphoedema, it has been reported that low-pressure bandages are as effective as high-pressure bandages and in addition, are more comfortable[37]. Also in this area, further research is an absolute requirement.

References

1. Moffatt CJ. (2005) Lymphoedema bandaging in practice. In: *EWMA Focus Document: lymphoedema bandaging in practice.* MEP Ltd, London
2. Földi E, Jünger M, Partsch H. (2005) The science of lymphoedema bandaging. In: *EWMA Focus Document: lymphoedema bandaging in practice.* MEP Ltd, London
3. Moseley AL, Carati CJ, Piller NB. (2007) A systematic review of common conservative therapies for arm lymphoedema secondary to breast cancer treatment. *Ann Oncol.* 18: 639-646
4. Ko DSC, Lerner R, Klose G, *et al.* (1998) Effective treatment of lymphedema of the extremities. *Arch Surg.* 133: 452-458
5. Olszewski WL. (2008) Contractility patterns of human leg lymphatics in various stages of obstructive lymphedema. *Ann N Y Acad Sci.* 1131: 110-118
6. Cheville AL, McGarvey CL, Petrek JA, *et al.* (2003) Lymphedema management. *Semin Radiat Oncol.* 13: 290-301
7. Thomas S. (2003) The use of the Laplace equation in the calculation of sub-bandage pressure. *EWMA J.* 3: 21-23
8. Basford JR. (2002) The law of Laplace and its relevance to contemporary medicine and rehabilitation. *Arch Phys Med Rehabil.* 83: 1165-1170
9. Melhuish JM, Clark M, Williams RJ, *et al.* (2000) The physics of sub-bandage pressure measurement. *J Wound Care.* 9: 308-310
10. Moffatt CJ, Dickson D. (1993) The Charing Cross high compression four-layer bandage system. *J Wound Care.* 2: 91-94
11. Blair SD, Wright DD, Backhouse CM, *et al.* (1988) Sustained compression and healing of chronic venous ulcers. *BMJ.* 297: 1159-1161
12. Bruyne de P, Dvorák T. (1976) The pressure exerted by an elastic stocking and its measurement. *Med Biol Eng.* 14 (1): 94-96
13. Moore Z. (2002) Compression bandaging: are practitioners achieving the ideal sub-bandage pressures? *J Wound Care.* 11: 265-268
14. Schuren J, Mohr K. (2008) The efficacy of Laplace's equation in calculating bandage pressure in venous leg ulcers. *Wounds UK.* 4: 38-47
15. Schuren J. (2011) Compression unravelled. Margreff Druck GmbH, Essen Germany. 61-63.
16. Schuren J. (2011) *Compression unravelled.* Margreff Druck GmbH, Essen Germany. 28-33
17. Strössenreuther RHK, Klose G. (2006) Practical instructions for therapists: general requirements for compression bandages. In: Földi M, Földi E (eds). *Földi's textbook of lymphology.* 2nd Edition, Elsevier GmbH, Munich, Germany. 599-602
18. Schuren J, Mohr K. (2010) Pascal's law and the dynamics of compression therapy: a study on healthy volunteers. *Int Angiol.* 29: 431-435
19. Sochart DH, Hardinge K. (1999) The relationship of foot and ankle movements to venous return in the lower limb. *J Bone Joint Surg.* 81B: 700-704
20. Lentner A, Spath F, Wienert V. (1997) Limitation of movement in the ankle and talo-calcaneonavicular joints caused by compression bandages. *Phlebology.* 12: 25-30
21. Moffatt CJ, Edwards L, Collier M, *et al.* (2008) A randomised controlled 8-week crossover clinical evaluation of the 3M® Coban 2 Layer Compression System versus Profore to evaluate the product performance in patients with venous leg ulcers. *Int Wound J.* 5: 267-279
22. Schuren J. (2011) Compression unravelled. Margreff Druck GmbH, Essen, Germany. 40-47
23. Rivlin S. (1958) Gravitational leg ulcers in the elderly. *Lancet.* 271: 1363-1367
24. Moffatt C. (2002) Four-layer bandaging from concept to practice. *Lower Extremity Wounds.* 1: 13-26
25. White R, Schuren J, Konn D. (2003) Semi-rigid vs rigid glass fibre casting: a biomechanical assessment. *Clin Biomech.* 18: 19-27
26. Schuren J. (2011) Compression unravelled. Margreff Druck GmbH, Essen, Germany. 88-97.
27. Partsch H, Clark M, Bassez S, *et al.* (2006) Measurement of lower leg compression in vivo: recommendations for the performance of measurements of interface pressure and stiffness: a consensus statement. *Dermatol Surg.* 32: 229-238
28. Moffatt CJ. (2005) Lymphoedema bandaging in practice. In: *EWMA Focus document: lymphoedema bandaging in practice.* MEP Ltd, London
29. Moffatt CJ. (2004) Factors that affect concordance with compression therapy. *J Wound Care.* 13: 291-294
30. International Lymphoedema Framework. (2006) Best practice for the management of lymphoedema: international consensus. MEP Ltd, London
31. European Wound Management Association (2005). *EWMA Focus Document: lymphoedema bandaging in practice.* MEP Ltd, London
32. Morgan PA, Murray S, Moffatt CJ, *et al.* (2011) The experience of patients with lymphoedema undergoing a period of compression bandaging in the UK and Canada using the 3M™ Coban™ 2 compression system. *Int Wound J.* 8: 586-598
33. Moffatt CJ, Franks PJ, Hardy D, *et al.* (2011) A preliminary randomized controlled study to determine the application frequency of a new lymphoedema bandaging system. *Br J Dermatol.* Nov 7. doi: 10.1111/j.1365-2133.2011.10731.x. [Epub ahead of print]
34. Marston W, Vowden K. (2003) Compression therapy: a guide to safe practice. In: *European Wound Management Association. Understanding compression therapy: position document.* 11-16
35. Morgan PA, Murray S, Moffatt CJ, *et al.* (2012) The challenges of managing complex lymphoedema/chronic oedema in the UK and Canada. *Int Wound J.* 9: 54–69
36. Lamprou DAA, Damstra RJ, Partsch H. (2011) Prospective, randomized, controlled trial comparing a new two-component compression system with inelastic multicomponent compression bandages in the treatment of leg lymphedema. *Dermatol Surg.* 37: 1-7
37. Damstra RJ, Partsch H. (2009) Compression therapy in breast cancer related lymphedema: a randomized controlled, comparative study of relation between volume and interface pressure changes. *J Vasc Surg.* 49: 1256-1263

CHAPTER 4
Adapting compression bandaging for different patient groups

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This chapter focuses on lymphoedema compression bandaging (LCB). This cannot be properly described if it is not included within the holistic multidisciplinary approach used in the Best Practice Document of 2006[1]. While we have included images that demonstrate how to apply various types of bandages, these are for illustrative purposes only and should not replace the training and education required before performing compression therapy. In addition, methods of application and adaptation may vary across countries, so practitioners must apply therapy in accordance with local policies.

Definition
The terms multilayer lymphoedema bandaging and multi-component lymphatic bandaging are replaced by a more general term, lymphoedema compression bandaging (LCB). The best practice management of lymphoedema has a holistic multidisciplinary approach that includes:

- exercise/movement-to enhance lymphatic and venous flow and to maintain joint mobility
- swelling reduction and maintenance to reduce limb size/volume and improve subcutaneous tissue consistency through compression and/or massage, and to maintain improvements
- skin care to optimise the condition of the skin, treat any complications caused by lymphoedema and minimise the risk of cellulitis/erysipelas
- risk reduction to avoid factors that may exacerbate lymphoedema or induce complications
- pain management and psychosocial support
- information, support and enablement of self-management

Prior to treatment, patients should informed clearly and in a way adapted to their ability to accept it, that they will have to cope with lymphoedema during their whole life and that management only tries to prevent or reduce lymphoedema and its consequences on their life.

Swelling reduction and/or maintenance is achieved through decongestive lymphatic therapy (DLT), a combination of compression exercise/movement with or without manual lymphatic drainage (MLD), or simplified lymphatic drainage (SLD). Compression may be applied by LCB, compression garments, adjustable Velcro devices or mechanical intermittent pneumatic compression (IPC).

Assessment
The precise management programme required will be determined by the:

- site, stage, severity and complexity of the lymphoedema
- presence and nature of co-morbidities,
- previous lymphoedema treatments and their efficacy
- the patient's physical and psychological tolerance of treatments
- the patient's social situation, that is, their ability to access and maintain treatment and self management
- goals of treatment

Therefore, a comprehensive assessment is required to determine the most appropriate treatment regimen for the patient. This will encompass taking a thorough history and medical assessment, specialist investigations, and screening for co-morbidities and differential diagnosis. It will also involve assessment of mobility and function, pain, condition of skin and subcutaneous tissues and psychosocial impact of lymphoedema to determine any factors that may limit treatment options or impact negatively on the outcome of treatment.

Assessment is required to both determine the stage of lymphoedema and to provide a baseline from which management is planned, progress monitored and necessity for further referral is determined. The International Society of Lymphology (ISL) *(Table 1)* classification should be used to determine unilateral limb oedema; severity is based on the difference in the limb volume of the affected and unaffected limbs according to the criteria below:

- mild: <20% excess limb volume
- moderate: 20-40% excess limb volume
- severe: >40% excess limb volume

There is currently no formal system for the classification of the severity of bilateral limb swelling or lymphoedema of the head and neck, genitalia or trunk.

The severity of lymphoedema can also be based on the physical and psychosocial impact of the condition. Factors to consider include:

- tissue swelling – mild, moderate or severe; pitting or non-pitting
- skin condition – thickened, warty, bumpy, blistered, lymphorrhoeic, broken or ulcerated
- subcutaneous tissue changes – fatty/rubbery, non-pitting or hard
- shape change – normal or distorted
- frequency of cellulitis/erysipelas
- associated complications of internal organs for example, pleural fluid, chylous ascites
- movement and function – impairment of limb or general function
- psychosocial morbidity

Table 1: Lymphoedema stages[2,3]

Stage	Description
0	Sub-clinical or pre-lymphoedema; typically includes all patients who have had lymph node dissection. Swelling is not evident despite impaired lymph flow. This stage may last a long time
I	Accumulation of fluid and protein in tissue is noted. Pitting may be present. Elevation may influence the limb. Mild swelling (<20% excess limb volume vs unaffected limb)
II	Includes swelling that does not reduce with elevation; pitting is present with increased adipose tissue and fibrosis. Moderate swelling (20-40% excess limb volume vs unaffected limb). Since adipose tissue accumulation can be seen within the first year after lymphoedema occurs it is important to include adipose tissue hypertrophy in the staging[11].
III	Adipose tissue and fibrotic tissue may or may not show pitting; includes skin thickening and large limb volume (elephantiasis). This morbid condition occurs when lymphostasis and chronic inflammation develop into fibrosclerosis and additional tissue swelling. Severe swelling (>40% excess limb volume vs unaffected limb)
	NB: pitting can be present at all stages; in stage III it can dominate the swelling[4]

A more detailed and comprehensive classification applicable to primary and secondary lymphoedema remains to be formulated.

General strategy for the treatment of lymphoedema

Lymphoedema management of the limbs can be divided into three different phases:

- initial management
- transition management
- long-term management

Initial management

Initial management of limb lymphoedema will always involve psychosocial support, education, skin care, exercise/ movement, elevation and management of any concomitant medical conditions, pain or discomfort. According to the clinical assessment of the lymphoedema, the initial management may comprise decongestive lymphatic therapy aiming to acutely reduce swelling. The whole initial management is then called "intensive phase treatment". There is no evidence to support a particular duration of intensive therapy, but as explained in chapter 3, the greatest loss of volume is in the early part of treatment. In practice, the duration of the intensive phase varies between one to four weeks of treatment *(Figure 1)*.

Transition management

Following intensive treatment, some patients may benefit from a one to three month period of transition management before progressing to long-term maintenance of volume therapy.

Long-term management

The long-term management of lymphoedema focuses on limiting further deterioration of swelling, enhancing limb function and gaining long-term control of the condition. Support, education and encouragement are key to helping patients adjust to living with a long-term condition and maximising their ability to self-manage and achieve a sense of control.

Palliative management

This is discussed in chapter 6. It may be the approach of choice if a patient has a poor prognosis or the burden of intensive treatment is anticipated to outweigh the potential benefits. Treatment strategies are adapted to relieve the symptoms of lymphoedema, prevent complications and maximise quality of life.

Failure or relapse management

When there is a failure of the initial treatment or a deterioration of swelling, the patient can be considered for a new intensive phase of treatment.

The therapeutic objectives of bandaging within lymphoedema strategy

1. ***Swelling reduction***

   The objective of bandaging in the management of lymphoedema is to reduce swelling by applying external compression to the limb, facilitating limb function and shape improvement by softening subcutaneous tissues. There is no drug alternative. Lymphoedema compression bandaging as part of DLT is more efficient than hosiery in reducing swelling[5].

2. ***Maintaining limb volume***

   The objective of bandaging can also be to help maintain limb volume reduction or prevent swelling worsening. It is then an alternative or a complement to compression garments during the transition phase and above all during the long-term management phase. It can also be the treatment of choice in case of palliative care *(see chapter 6)*. Figure 2 summarises these objectives.

Optimal level of pressure in lymphoedema compression bandaging

The optimal level of pressure that should be applied in order to obtain the best volume reduction is not known. The pressure produced by a compression bandage can be predicted according to Laplace's law *(see chapter 3)*, so that sub-bandage pressure will rise with increasing bandage tension and number os layers, and decrease with increasing limb circumference and bandage width. However, as showbn in chapter 3, graduated compression profiles are rarely achieved in practice according to Laplace's law, although compression profiles improve with training.

For a large limb requiring high level of compression, the desired pressure may be achieved by increasing the number of bandage layers applied and increasing the tension used during application. The dosage of the tension while applying bandages depends on the manual force which is used to stretch the bandage.

In clinical daily practice, it is not recommended to measure pressure under the bandage. In training it is highly recommended that, practitioners gain experience of bandaging using different pressure from mild (< 20mmHg) to very strong (>60mmHg)[6] to help them control sub-bandage pressure. Multi-component inelastic bandages with initial low pressures between 20 and 30mmHg applied on the arm with lymphoedema for two hours, achieved a higher degree of volume reduction than higher pressures (44 to 58mmHg). Similarly, multi-component inelastic bandages with initial high pressures of 56 to 88mmHg applied to a lymphoedematous leg for two days, were associated with less swelling reduction[7].

When bandage tolerability is optimised, bandage pressures should be continuously adapted toward the best volume reduction. If side effects are present (skin fragility, arterial or neurologic deficiencies, ankle immobility), bandage pressures should be continuously adapted toward the best tolerance.

Figure 1: Initial management of lymphoedema - (Reproduced from the Best Practice for the Management of Lymphoedema. International consensus document, with kind permission of MEP Ltd)

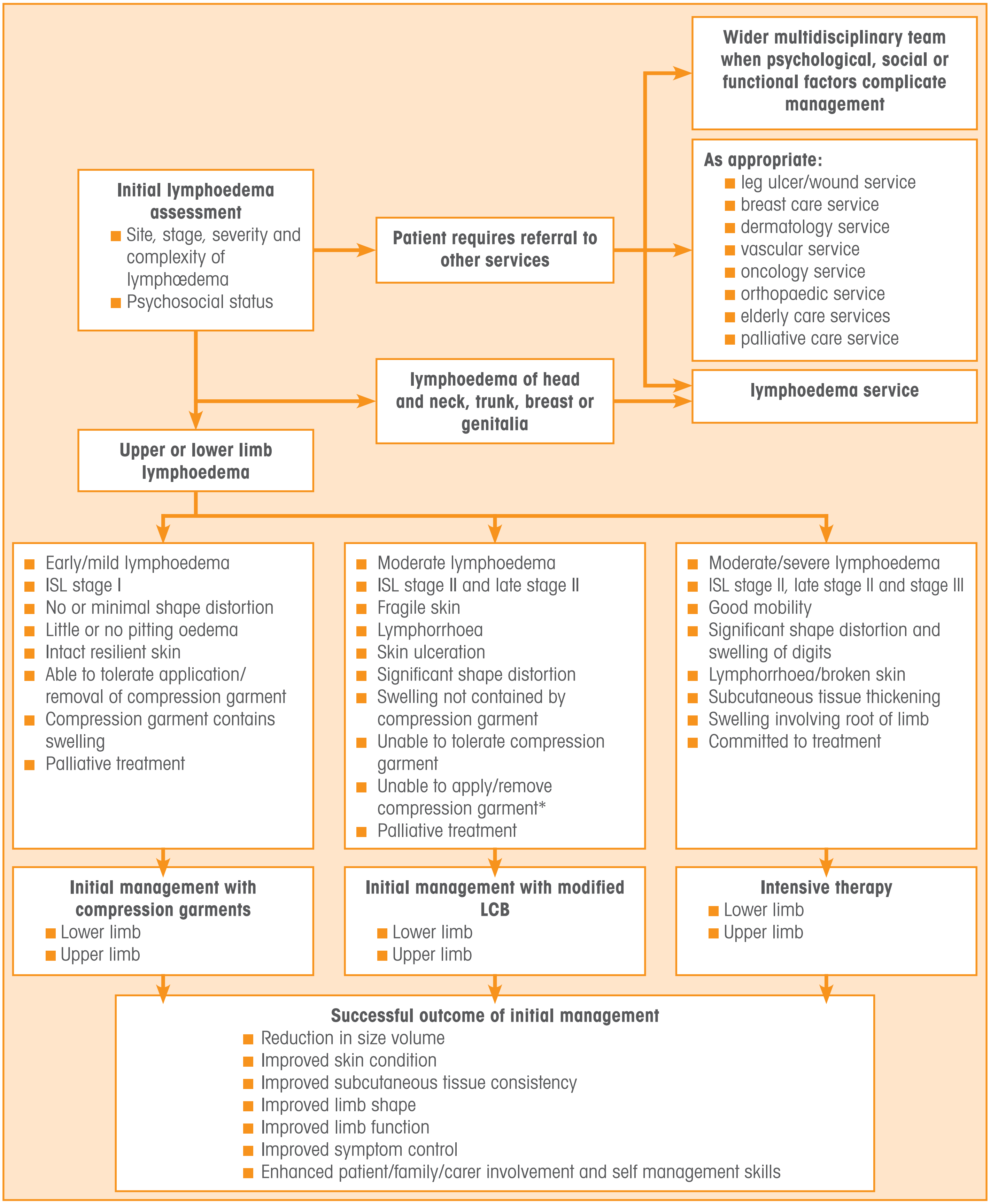
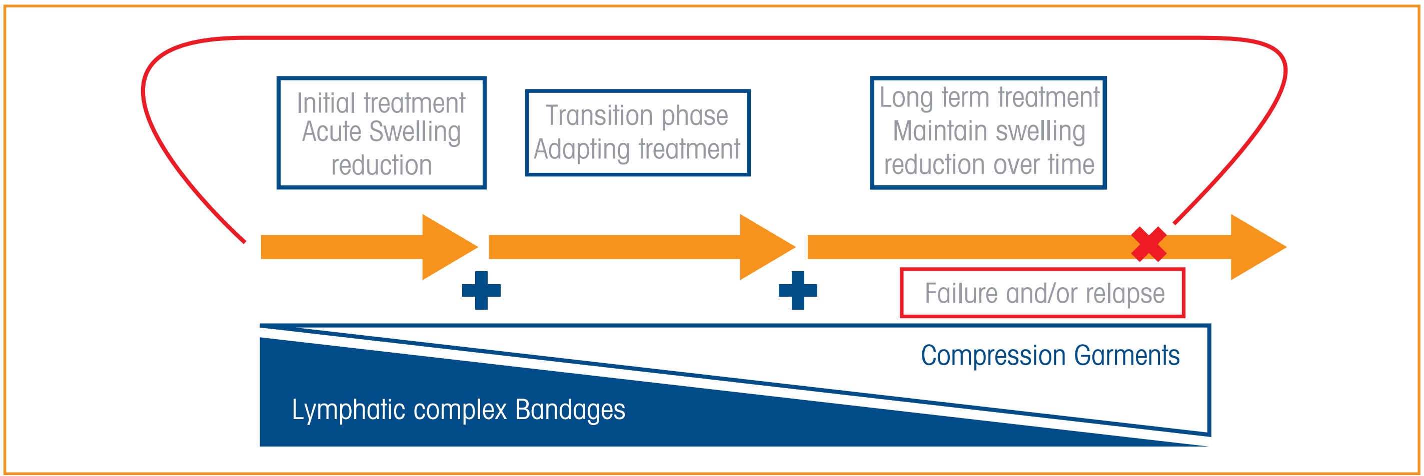


Figure 2: The use of compression bandages or garments in lymphoedema treatment



Characteristics of lymphoedema compression bandaging

Lymphoedema compression bandaging (LCB) is the key element of decongestive lymphatic therapy. For some patients, it may also form part of their transition, long-term or palliative management. Traditional LCB uses different components, but whichever are used, LCB is applied for three main purposes:

- to provide a protective, absorbent layer between the skin and other bandages
- to protect bony prominences, normalise shape, and equalise the distribution of pressure produced by the compressive bandage layers using padding of various thicknesses and densities
- to provide external compression by applying layers of inelastic bandages or, in some cases depending on the tolerance of the treatment, of long-stretch bandages

New materials providing less bulky padding material have been developed which show very promising results, mainly due to enabling greater joint mobility[7-9]. LCB uses compression bandages able to produce high working pressures during muscle contraction. The peak of pressure produces a massaging effect on the subcutaneous tissues and favors venous and lymphatic flow.

With inelastic bandages, the most widely used lymphatic compression bandage, the peak of pressure is very high and the resting pressure very low. With long-stretch bandages, the elastic bandage provides continuous pressure with little variation between resting and working pressures.

The indications for use of lymphatic compression bandage rather than a compression garment with inelastic bandages are:

- distorted limb shape
- tissue thickening
- limb too large to fit compression garment
- lymphorrhoea
- lymphangiectasia
- fragile, damaged and ulcerated skin
- pronounced skin folds

The contraindications for lymphatic compression bandage are

- severe arterial insufficiency
- uncontrolled heart failure
- severe peripheral sensitive neuropathy

Adapting LCB

LCB can be adapted in many ways to the needs of the patients by padding or not padding, using either short or elastic bandages and by modifying the frequency and the duration of bandaging. Velco-band wraps can be readjusted by the patients[11].

Padding

The frequency of distorted limb shape and of tissue thickening has led to the use of padding for both safety (protection of vulnerable pressure points around the ankle) and equalisation of the applied pressure over the whole limb. The application of thick padding can make bandages bulky, hot and impede joint mobility. Moreover, it has been recently shown that the padding layers could lead to a reduction rather than an optimisation of the applied pressure and can limit the efficacy of bandages[12].

New products have been developed allowing less bulky LCB and easier movement. These include Mobiderm® padding bandages[18]. Alternatives to multi-component lymphoedema compression bandaging are also being developed on the basis of a two-component compression system[8,13] without thick padding.

The use of elastic bandages

In some situations, the inelastic bandages used in LCB may be replaced with a multi-component elastic bandage regimen. The bandage system as a whole achieves the characteristics of an inelastic system because of the stiffness produced by the friction of the superimposed layers of the bandage. The addition of a cohesive or adhesive elastic bandage may produce even higher working pressures if needed. However, the resting pressure remains higher than with inelastic system. This sustained resting pressure may be useful when the:

- patient is immobile
- ankle joint is fixed and the calf muscles are unable to play their role as a pump
- patient has both lymphatic disease and venous ulcer
- patient has proven venous insufficiency
- expected volume loss is large, so that it helps to increase time worn

Frequency of bandage change

As yet, there is no evidence to indicate how frequency of bandage change affects speed of swelling reduction. The use of multi-component inelastic bandage on a lymphatic limb is associated with a rapid sub bandage pressure drop of nearly 50% of the initial value within two hours and two third after 24 hours[10]. These bandages should be reapplied when they become too loose to keep the level of compression in an effective range. Clinical experience recommends that during intensive treatment, multi-component bandages should be changed at least daily during the first week of treatment. From a practical point of view, this will allow the professional to ensure that the tolerance of the bandage is good, to reapply compression with effective pressure and to avoid excessive bandage slippage.

When skin fragility, arterial or neurological deficiencies and ankle immobility are present, bandage pressures should be continuously adapted on the basis of a daily change of bandages *(Figure 3)*. This includes those with:

- moderate concurrent lower limb peripheral arterial occlusive disease (ABPI 0.5-0.8). N.B. Patients with ABPI <0.5 (critical ischaemia) may not receive sustained compression therapy
- a neurological deficit that will make sensing complications difficult
- cancer requiring palliative treatment
- co-morbidities requiring less aggressive reduction in swelling

According to the therapy regimen and wound/skin care requirements, it may be possible to reduce the frequency of change to two to three times per week when tolerance is good. When tolerability of the bandages is optimum, then bandage frequency should be continuously adapted toward the best volume reduction and fewer bandage changes. Cohesive or adhesive bandages may be very useful in this situation. Interestingly, new bandages such as Coban® cohesive system allow a reduction in bandage change frequency[9].

Duration of the bandaging

Daily bandaging is usually undertaken for one to four weeks of treatment. The duration should be adapted to the obtained swelling reduction. As a compromise, shorter treatments have been developed to improve the patient's acceptability of the treatment. If daily bandaging is performed the initial pressure should not exceed 30mmHg on the upper and >60mmHg on the lower extremity[7]. The reduction of the volume excess is mainly obtained during the first week of the treatment whatever the bandage and then slows.

Night application

During the initial phase, and when the objective is to have a reduction of swelling, bandages are usually kept on during the night. For those using both elastic and inelastic bandages, the elastic component is usually taken away because of a variable tolerance of the resting pressures during the night. During long-term treatment, bandages are often used as a complement to compression garments and are recommended during the night.

Using bandaging in lymphoedema management

Initial management

Initial management of limb lymphoedema will involve psychosocial support, education, skin care, exercise/movement, elevation and management of any concomitant medical conditions, pain or discomfort *(Figure 1)*. This also includes treatments aiming to reduce limb volume.

Compression hosiery option

Patients with mild limb lymphoedema (ISL stage I), minor pitting, no significant tissue changes, no or minimal shape distortion, or palliative needs may be suitable for initial management with compression hosiery. This management also involves

Figure 3 a-f: An example of bandage modification in a patient with neurological and motor damage

Day 1 - *3a:* *Clinical assessment; pitting oedema, complete neurological deficiency and a finger wound*

Day 1 - *3b:* *Careful application of cotton bandage, Mobiderm® padding and short-stretch bandage at low pressure on the finger toward the best tolerability*

Day 1 - *3c:* *Day one clinical response: good tolerance but poor swelling reduction on the fingers*

Day 2 - *3d:* *Adaptation of the bandage with Mobiderm® padding on the fingers, short stretched bandage with higher pressure application on the fingers*

Day 2 - *3e:* *LCB of the hand and the arm*

Day 2 - *3f :* *Improved swelling reduction of the hand and fingers after two days of treatment*

psychosocial support, education, skin care, exercise/movement, management of any concomitant medical conditions, pain and discomfort.

Intensive therapy option

The combination of skin care, exercise, MLD and LCB are often known as decongestive lymphatic therapy (DLT). The term intensive therapy has been used in this document to denote a holistic approach that includes education, psychosocial support and pain management, and that may also include SLD. Intensive therapy is used in patients with ISL stage II, late stage II and stage III limb lymphoedema. The objectives of treatment are to reduce swelling so that compression hosiery can be applied and to prepare patients and carers for self-management.

Standard intensive therapy

Patients undergoing standard intensive therapy must be carefully selected and be willing and able to commit physically and emotionally to daily intensive therapy, including participation in exercise programmes.

An intensive standard therapy uses LCB with short-stretch bandages which are changed daily. The level of compression used is the most efficient one on the basis of a daily evaluation of the volume reduction. High levels of compression are usually used. Any tolerance issue will lead the practitioner to stop the intensive standard therapy and propose an adapted regime. Intensive therapy programmes are likely to be undertaken for a period of one to four weeks. During this time treatment should be evaluated continuously and appropriate alterations made according to patient need and the effectiveness of the selected regimen. Appropriate training is required for all practitioners who deliver intensive therapy regimens.

Modified intensive therapy

Modified intensive therapy with high pressure

This involves skin care, exercise/movement, elevation, MLD/SLD and LCB with inelastic bandages undertaken three times weekly. Suitable patients are able to tolerate high levels of compression, but unable to commit to standard intensive therapy for physical, social, psychological or economic reasons, for example those who are elderly, obese or have poor mobility. In this case, new cohesive treatments provide interesting options[13].

Modified intensive therapy with reduced pressure

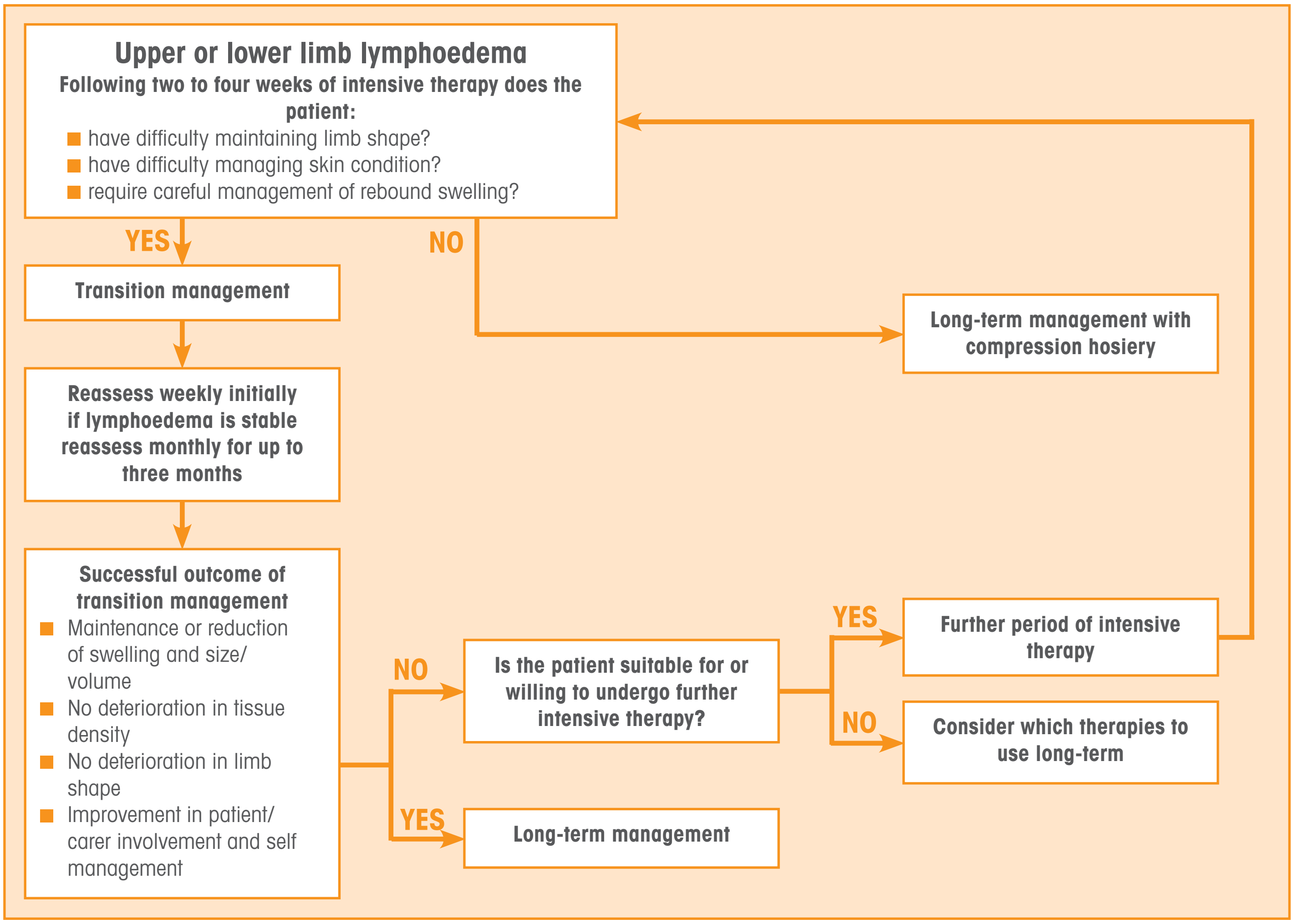
This involves skin care, exercise/movement, elevation, SLD, LCB +/– intermittent pneumatic compression (IPC) undertaken daily or three times weekly according to the need of evaluation of the efficiency and tolerance of the treatment. Patients are selected for this treatment when high levels of compression are either unsafe or difficult to tolerate. This includes those with:

- moderate concurrent lower limb peripheral arterial occlusive disease (ABPI 0.5-0.8). N.B. Patients with ABPI <0.5 (critical ischaemia) may not receive sustained compression therapy
- a neurological deficit that will make sensing complications difficult
- lipoedema/lipolymphoedema; lower levels of compression may be easier to tolerate
- cancer requiring palliative treatment
- co-morbidities requiring less aggressive reduction in swelling

Intensive therapy for lymphovenous disease

This involves skin care, exercise/movement, elevation, and LCB +/– IPC undertaken either daily or three times weekly. Treatment frequency will be determined by the severity of the oedema, skin condition and rate of swelling reduction. Suitable patients include those who have had conservative therapy for deep vein thrombosis or those who have post-thrombotic syndrome, who may be at risk of developing or have existing leg ulceration. A recent review concluded that immediate ambulation with appropriate compression does not significantly increase the incidence of pulmonary embolism, produces a faster reduction of pain and swelling, and reduces the severity of post-thrombotic syndrome[14]. LCB may need to be modified in the presence of

Figure 4: Transition management – upper and lower limb lymphoedema - (Reproduced from the Best Practice for the Management of Lymphoedema. International consensus document, with kind permission of MEP Ltd)



venous ulceration, peripheral arterial occlusive disease or immobility. IPC may be particularly useful for the many patients with venous ulceration who have poor mobility and are unable to elevate their legs[15-17].

N.B. In severe cases with significant limb distortion, oedema and tissue thickening, fitter patients may benefit from a period of standard intensive therapy.

Transition and long-term management

Maintaining improvements following intensive therapy for long term swelling usually involves compression garments. However, for some patients, the most appropriate form of compression in the long term will be bandaging or a combination of compression garment or bandaging. Bandages can also form part of the treatment during the transition period or for palliative management *(Figures 4 and 5)*.

Management of the limbs

Lower limb

Bandaging the toes and foot

Toes should be bandaged if they are swollen or show papillomatosis *(Figure 6)*. If not, they should be monitored and bandaged if they swell during the treatment of the limb. The presence of lymphoedema can be confirmed by a positive Stemmer sign; in a healthy person, a fold of skin can be pinched and lifted up at the base of the second toe. If the skin fold cannot be raised, this is a positive Stemmer sign. However, a negative sign may occur in proximal descending lymphoedema and does not exclude lymphoedema. Forefoot swelling can require padding *(Figure 7)*. Foam padding aids oedema reduction around the malleoli *(Figure 8)*.

A thick bandage does not allow appropriate fitting of the foot into the shoe. An alternative to the standard LCB of the foot is to use an adhesive non elastic bandage, applied at full stretch on the protective first cotton layer[19] *(Figure 9)*. Bandaging of the toes and the foot can be taught to the patients as self-management bandaging.

Bandaging the leg

Application of under-padding to the leg *(Figure 10)* is followed by spiral bandaging of the lower leg with inelastic bandage *(Figure 11)*.

Figure 5: Compression choices in transition management for upper or lower limb lymphoedema - (Reproduced from the Best Practice for the Management of Lymphoedema. International consensus document, with kind permission of MEP Ltd)

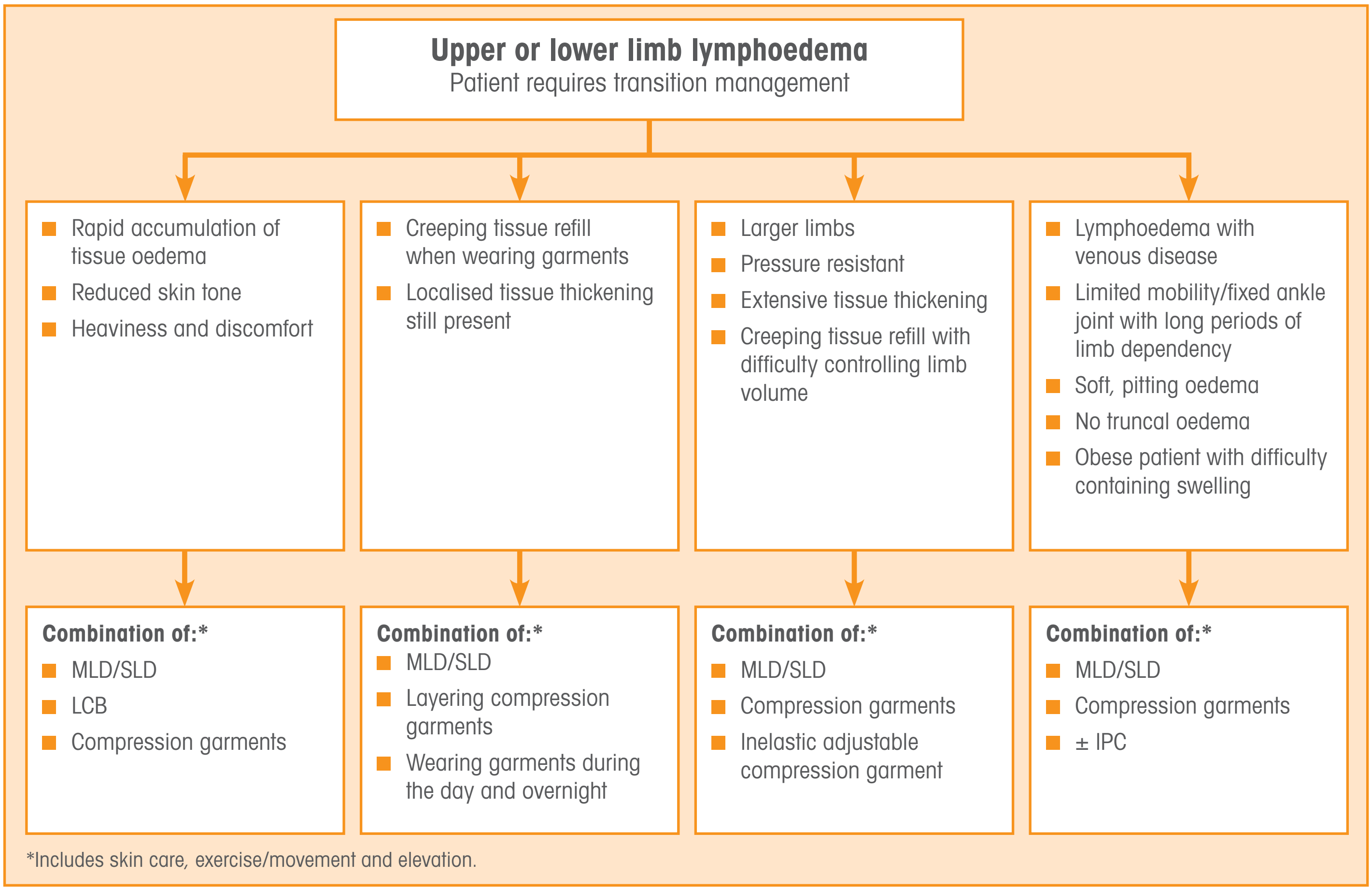


Figure 6 a-d: Bandaging the toes and foot

6a: Anchor the 4cm conforming bandage with one complete circle at the base of the toes.

6b: Take the bandage to the distal end of the big toe.

6c: Bandaging should be distal to proximal starting from the base of each toenail with a turn around the base of the toes before starting the next toe.

6d: Keep slight tension on the bandage. Avoid making creases on the underside of the toes. The little toe can be bandaged on its own, with the adjacent toe, or left unbandaged. On completion check that the bandage does not slip off, and check the toes for cyanosis and sense of touch.

Figure 7: Forefoot swelling

Foam padding can be applied to the forefoot and fastened with a toe bandage to increase local pressure.

Figure 8: Padding for retromalleolar oedema

Figure 10: Application of tubular bandage to lower leg

Figure 9 a-d: Bandaging the toes and forefoot with adhesive bandages

9a: Swollen toe and forefoot with papillomatosis

9b: Standard bandage with inelastic bandage of the toes and forefoot

9c: Protection of the skin of the foot under the adhesive bandage

9d: Adhesive short stretch bandage of the foot allowing footwear and helping walking without slippage of the bandage

Figure 11 a-e: Bandaging the lower leg and application of underpadding

11a: Application of underpadding to lower leg

11b: Anchor an 8cm inelastic bandage with a turn around the base of the toe

11c: Bandage the foot using spiral technique. Use figure of eight technique around the ankle. Continue up the leg using spiral technique with any remaining bandage.

11d: Bandage the lower part of the leg using a 10cm inelastic bandage and spiral technique, and continue up the limb

11e: The end of the tubular bandage can be folded back and concealed under the next layer of bandage.

Figure 12 a-f: Spiral bandaging of the thigh with inelastic bandage

12a: If swelling occurs above or around the knee, the thigh should be bandaged. Ensure the cotton tubular bandage is long enough to cover the thigh.

12b: After bandaging the lower leg, allow the patient to stand with the knee slightly bent. Apply soft synthetic wool padding to the knee and thigh.

12c: At the popliteal fossa, double or triple the padding or apply a foam insert.

12d: Ask the patient to shift their weight to the leg to be bandaged, providing support if necessary, so that the thigh can be bandaged with the musclecontracted. Use a 10cm or 12cm inelastic bandage and apply a loose turn to anchor the bandage below the knee.

12e: After anchoring the bandage obliquely across the popliteal fossa, make a circular turn once around the distal aspect of the thigh. Then continuedown to the starting point of the bandage, wrapping the flexed knee with figure of eight turns. Then wrap through the popliteal fossa over thepatella using spiral technique.

12f: Continue the bandage up the thigh to the groin using spiral bandaging technique. The next layer is applied in the same way, but in the opposite direction.

Thigh bandaging

If swelling occurs above or around the knee, the thigh should be bandaged *(Figure 12)*.

Addressing specific problems

Skin folds

Deep skin folds can occur on the toes and around the ankle. The skin folds must be padded using orthopoedic padding *(Figure 13)*.

Figure 13: Padding skin folds

Upper limb

Finger and hand bandaging

The hand should be bandaged in most cases as hand swelling nearly always occurs during upper limb lymphoedema *(Figure 14)*. Soft synthetic wool or soft foam under-padding is used *(Figure 15)*. Padding can be used for dorsal or palmar oedema *(Figure 16)*. Bandaging of the fingers and the hand can be taught to the patient as self-management bandaging.

Bandaging of the arm

Application of tubular bandage and foam under padding is followed by spiral bandaging of the lower arm with inelastic bandage *(Figure 17)*.

Management of midline lymphoedema

The management of midline lymphoedema, that is, lymphoedema of the head and neck, trunk, breast or genitalia, can be particularly challenging, especially because of the lack of standardised objective measurement methods to evaluate treatment effects and to facilitate measurement for appropriate compression garments. Practitioners treating midline lymphoedema will be trained at specialist level and a multidisciplinary approach is needed.

The individually tailored management plan for patients with lymphedema of the trunk and of head and neck is likely to include:

- daily skin care
- exercise/movement
- massage
- compression bandaging (challenging because of the anatomy of the areas and of poor tolerance of compression)
- bespoke compression garment and individualised foam pads
- self monitoring

Figure 14 a-e: Finger and hand bandaging

14a: *Applying a tubular bandage*

14b: *Begin with the palm of the hand facing down. Make one loose complete turn with the 4cm conforming bandage around the wrist to anchor it.*

14c: *Ask the patient to spread their fingers and thumb. Then begin to bandage the hand. Wrap eachfinger individually.*

14d: *Bring the bandage over the back of the hand to the fingertips without tension. Bandaging should be distal to proximal, leaving the fingertips uncovered. Make circular turns around eachfinger. Maintain light tension on the bandage.*

14e: *On completion check that the bandage does not slip off, and check digits for cyanosis andsense of touch.*

Figure 14 f-j: Application of the 3M™ chronic oedema system

14f

14g

14h

14i

14j

The 3M™ Coban system involves a single thin comfort padding, moulded to the limb, and a stiff outer casing.

Figure 15 a-b: Applying foam underpadding

***15a:** Anchor an 8cm inelastic bandage with a turn around the base of the toes.*

***15b:** Bandage the foot using spiral technique. Use figure-of-eight technique around the ankle. Continue up theleg using spiral technique with any remaining bandage.*

Figure 16: Padding for dorsal and palmar oedema

Truncal lymphoedema

Lymphoedema can affect the chest, back, abdomen, buttocks, breast or genitalia in isolation or in combination with limb oedema. The management strategies described for breast and genital lymphoedema can be combined, when necessary, with those for the management of limb lymphoedema.

Breast lymphoedema

There is little consensus on the best approach to the management of breast lymphoedema. The anatomy of the area may make bandaging difficult. However, prevention, early diagnosis and supportive care have much to offer. MLD and SLD form an important part of treatment with the use of bras. Tissue thickening may be softened by using customised foam pads.

Genital lymphoedema

Genital lymphoedema can be highly incapacitating and extremely difficult to manage. Careful monitoring for signs of infection and scrupulous skin care are crucial. MLD and SLD are important treatment components. When genital lymphoedema and lower limb lymphoedema co-exist, treatment of the lower limb swelling may exacerbate the genital oedema.

Figure 17 a-d: Spiral bandaging of the arm with the inelastic bandage

17a: *Begin with a 6cm inelastic bandage applied loosely at the wrist with one turn to anchor. Forpatients with small hands, a 4cm bandage may be used instead.Wrap the hand with the fingersspread. Use moderate tension onthe bandage. Cover all of the handincluding the knuckles and palmof the hand at the base of the thumb to mid palm.*

17b: *Use spiral technique to bandage the forearm with any remaining material. Overlap the second inelastic bandage (8cm or 10cm) with the end of the first.Bandage the forearm with the muscles tightened by asking thepatient to make a fist. This is to prevent excess pressure increasein this part of the arm during active movement that might worsen venous and lymphaticreturn.*

17c: *Use figure of eight turns tobandage the elbow while it is slightly flexed. This further protects the inner elbow.*

17d: *Start the final inelastic bandage (10cm) at the wrist.Apply it using spiral technique in areverse direction to cover the whole arm up to the armpit. This helps to maintain an optimal pressure gradient from the distalto proximal part of the arm.*

Women usually require custom made compression garments with anatomically contoured stasis pads to treat thickened and swollen areas. Bandaging is difficult to manage. In men, LCB may be used and self-bandaging taught. Depending on the degree of swelling, supportive close fitting shorts containing Lycra (such as cycle shorts) may be a useful alternative to ready to wear or custom made scrotal supports or compression garments. In either gender, surgical management may sometimes be necessary.

Lymphoedema of head and neck

Lymphoedema of the head and neck is often a complication of cancer or secondary to tissue damage in this area. MLD and SLD are key elements of treatment. Low pressure compression may be applied using bandaging or custom made garments. Low density foam pads can be used to apply localised pressure. Compression should never be applied to the neck area. Surgical management of eyelid lymphoedema may be considered.

Conclusion

Management of complex lymphoedema requires highly skilled, specialist practitioners to work in partnership with the patient and family to facilitate timely and appropriate management of both the lymphoedema and associated side-effects.

This chapter has explored some of the approaches to adapting compression bandaging to meet the needs of those with complex needs. The case studies outlined in box 3 demonstrate how this can be achieved by working with the patient and their family within a solution orientated care framework.

Box 3: Two case studies - Kindly supplied **by Anna Rich and Karen Dring**, Clinical Nurse Specialists, Lymphoedema, Queen's Medical Centre, Nottingham, UK

CASE STUDY ONE

Jane, a 40 year old lady with spina bifida and wheelchair bound, developed unilateral oedema 15 years previously following a fracture of her left leg. She had developed a long term non-healing wound to the dorsum of the foot.

On examination, she had pitting oedema in her left foot, causing loss of shape and the dorsum to overhang the toes *(Figure 18)*. There was an ulcer on the dorsum of the foot measuring 6.5cm x 6cm wide and approx 4cm deep *(Figure 19)*. The delay in wound healing was related to the oedema, caused and exacerbated by the limb dependency.

Thus, we aimed to manage the foot oedema to promote wound healing. Individual toe bandaging was not possible due to the extent of the dorsum overhang; conventional bandaging alone would not address the most troublesome area of swelling.

After discussion with Jane, we agreed to use short stretch compression with a stump type bandage. Skin care was performed; the wound was dressed initially with idoflex and atrauman. The leg was then covered with yellow line Tubifast® and cellona applied as padding, used to shape the leg and the foot. An 8cm short stretch cohesive bandage was then applied in a spiral from the metatarsal area to the ankle and then a 10cm from the ankle to below the knee. The dorsal overhang was also padded with cellona, before application of 8cm strips of the adhesive bandage were applied over the toe area to form a stump bandage. Once we had ascertained that Jane was able to tolerate the spiral application this was increased to a figure-of-eight *(Figures 20 to 22)*. Compression was introduced slowly due to Jane's existing co-morbidities and the lack of sensation in her lower legs. Bandaging initially took place on alternate days, reducing to weekly over a four month period. The wound was dressed according to clinical presentation.

The dorsal area reduced by over 4cms, improving the overall shape of the foot and facilitating healing of the wound. Jane is now successfully maintained in class 2 (RAL) flat knit hosiery *(figure 23)*.

CASE STUDY TWO

Sarah developed spontaneous onset of swelling 20 years ago which was further exacerbated by recurrent episodes of cellulites. Sarah has very poor mobility, a BMI of 59 and is partially sighted, hard of hearing with poor balance, epilepsy and anxiety.

On assessment: Bilateral oedema extending into the thigh; both legs were grossly misshapen with skin changes associated with chronic oedema *(Figures 24 & 25)*. Over the last 10 years she had experienced tissue breakdown and lymphorrhoea, and was managed in the community with below knee short stretch cohesive bandages. These treatments were not successful due to bandage slippage and did not address the oedema in the thighs.

We initially treated her with short stretch bandages toe to thigh. This required a large amount of padding to reduce slippage. Although this was somewhat successful, her mobility was further limited and slippage was not totally eliminated. After discussion with Sarah she agreed to try a new 2 layer system, previously shown to reduce slippage. Furthermore, if successful the bandage would reduce visits to the clinic for Sarah and reduce manual handling pressures for staff.

The 2 layer system was initially applied three times a week and then reduced to twice weekly. Sarah was able to tolerate both legs with little effect on her mobility *(Figure 26)*. There was very little slippage and Sarah found the bandages very comfortable and was pleased she could continue with her own footwear. After 3 weeks of treatment with the 2 layer bandaging system there was a loss of 3,302ml to the right leg and 3,831ml to the left leg. Weight upon starting the bandaging had been 140kg and was now 133kg, with no further leakage and a huge improvement in shape and skin condition. Sarah is now maintained in class 3 (RAL) flat knit hosiery.

Figure 18

Figure 19

Figure 20

Figure 21

Figure 22

Figure 23

Figure 24

Figure 25

Figure 26

References

1. International Lymphoedema Framework. (2006) *Best practice for the management of lymphoedema: international consensus.* MEP Ltd, London
2. International Society of Lymphology (2009) The Diagnosis and treatment of Peripheral Lymphedema. Consensus Document. Lymphology. 42 51-60
3. Poage E, Singer M, Armer J. *et al.* (2008) Demystifying Lymphedema: Development of the Lymphedema Putting Evidence into Practice Card. *Clinical Journal of Oncology Nursing.* Vol 12. No 6; 951-964
4. Brorson H, Ohlin K, Svensson B, *et al.* (2008) Controlled compression therapy and liposuction treatment for lower extremity lymphedema. *Lymphology.* 41: 52-63
5. Badger C, Preston N, Seers K, *et al.* (2004) Physical therapies for reducing and controlling lymphoedema of the limbs. Cochrane Database Syst Rev. 18 (4): CD003141
6. Partsch H, Clark M, Bassez S, *et al.* (2006) Measurement of lower leg compression in vivo: recommendations for the performance of measurements of interface pressure and stiffness. Dermatol Surg. 32: 224–334
7. Partsch H, Damstra RJ, Mosti G. (2011) Dose finding for an optimal compression pressure to reduce chronic edema of the extremities. *Int Angiol.* 30. (6): 527-33
8. Lamprou DAA, Damstra RJ, Partsch H. (2011) Prospective, randomized, controlled trial comparing a new two-component compression system with inelastic multicomponent compression bandages in the treatment of leg lymphedema. *Dermatol Surg.* 37 (7): 985–991
9. Moffatt CJ, Franks PJ, Hardy D, *et al.* (2012) A preliminary randomized controlled study to determine the application frequency of a new lymphoedema bandaging system.Br J Dermatol. 1 66 (3): 624-32
10. Damstra RJ, Brouwer ER, Partsch H. (2008) Controlled, comparative study of relation between volume changes and interface pressure under short-stretch bandages in leg lymphedema patients. Dermatol Surg. 4 (6): 773-8; discussion 778-9. Epub 2008 Mar 10
11. Damstra R, Partsch H. (2012) Prospective, Randomized Controlled Trial Comparing the Effectiveness of adjustable compression Velcro-wraps versus Inelastic Multilayer Compression Bandages in the initial Treatment of Leg Lymphedema. *J Vasc Surg.* (in print)
12. Mosti G, Mattaliano V, Partsch H. (2008) Influence of different materials in multicomponent bandages on pressure and stiffness of the final bandage. *Dermatol Surg.* 34 (5): 631-9
13. Moffatt C, Edwards L, Collier C, *et al.* (2008) A randomised, controlled 8-week crossover clinical evaluation of the 3M™ Coban™ 2 Layer Compression System versus Profore™ to evaluate produce performance in patients with venous leg ulcers. *Int Wound J.* 5 (2): 267-79
14. Partsch H. (2005) Ambulation and compression after deep vein thrombosis: dispelling myths. *Semin Vasc Surg.* 18: 148-52
15. Franks PJ, Moffatt CJ, Connolly M, *et al.* (1995) Factors associated with healing leg ulceration with high compression. *Age Ageing.* 24 (5): 407-10
16. Vowden K. (2001) The use of intermittent pneumatic compression in venous ulceration. *Br J Nurs.* 10 (8): 491-509
17. Alpagut U, Dayioglu E. (2005) Importance and advantages of intermittent external pneumatic compression therapy in venous stasis ulceration. *Angiology.* 56 (1): 19-23
18. Vignes S. (2012) Management of limb lymphoedema. *Rev Med Interne.* 33(5): 268-72
19. Evrard-Bras M, Coupe M, Quéré I, *et al.* (2002). Treatment of Lymphoedema. Montpellier's experience. *Rev Med Intern. 23:* 408-13

CHAPTER 5
Dermatological issues in lymphoedema and chronic oedema

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Structure and functions of the skin

In order to understand lymphoedema skin breakdown and thus consider the most appropriate treatment options and strategies for patient education, the normal function and structure of the skin must be understood.

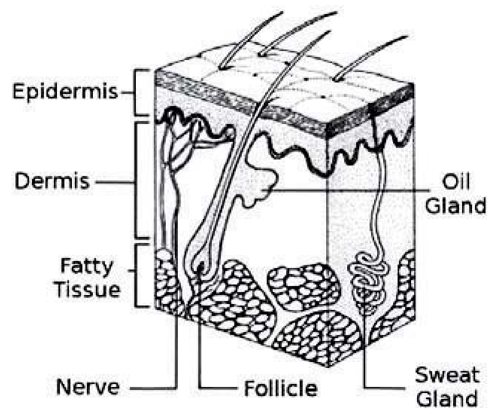
The skin is the largest organ of the body and has a number of functions:

- it provides a barrier to protect the body from the environment and infection through its immune function
- it regulates temperature
- it detects sensations such as pressure, vibration and temperature
- it synthesises vitamin D
- it acts as an excretory organ

Skin varies in thickness in different parts of the body; it is thinnest on the lips and around the eyes, thickest on the soles of the feet. It is strong and flexible, mainly due to the subcutaneous tissue, elastic fibres and collagen in the dermis, the number and volume of which decline as we age, making the skin more fragile.

The 'skin barrier' is located in the stratum corneum, or upper layers of the epidermis *(Figure 1)*. Normally, this barrier protects the underlying skin from penetration by irritants and allergens and also prevents trans-epidermal water loss (TEWL) from the body[1]. In healthy skin, the skin barrier functions well due to its structure: corneocytes, which contain water and proteins including natural moisturising factor (NMF), are laid down in a 'brick' formation, held together by 'mortar' comprising lipid lamellae; extracellular lipids such as ceramides, and corneodesmosomes in the lower layers of the epidermis[1]. Degradation of the corneodesmosomes in the differentiating stratum corneum results in a discontinuous aqueous 'pathway' between the lipid rich extracellular matrix. As the intercorneocyte water swells due to the humectant (water attracting) action of the NMF, the hydrophilic phase may form a continuous water permeable lacunar system. NMF contains urea, itself a humectant, and acids that maintain the low pH of the skin (5.5), so is an important component.

Figure 1: Schematic of the skin *(ack. WPClipart)*



Renewal of the stratum corneum is a constant process. This is regulated by the action of proteases which break down the corneodesmosomes. This then which in turn causes the shedding of surface corneocytes (desquamation), and by the action of Lipolytic 'processing enzymes'. If however, the process is affected by an imbalance of proteases and protease inhibitors, or as in genetic diseases of cornification of lipid processing enzymes, the stratum corneum may thin and crack, potentially allowing the entry of irritants and allergens. In addition, decreased levels of NMF, particularly urea, and the breakdown of the lipid lamellae, cause skin to dry as in effect, the 'mortar' holding the corneocyte 'bricks' together, crumbles, leading to greater TEWL. Over-hydration of the skin (occlusion, prolonged hydration) will contradictorily lead to water loss by enlarging and connecting the aqueous lacunae between the lipid layers, making the barrier 'leaky'[2].

In inflammatory skin diseases, infiltration of the skin is by inflammatory cells from the surrounding tissues or via diapedesis out of the blood vessels. Secreted proteins influence different enzymatic functions at the cellular and extracellular levels.

Proteolysis of cell surface and extracellular matrix molecules is intrinsically linked to cell function. The inflammatory reaction can impact on the epidermis and underlying dermis, profoundly disturbing the cellular turnover, maturation, functions and synthesis of the skin barrier elements. Acute and chronic eczema result in vesicular lesions leading to erosions which easily get colonised or infected. In desquamative inflammatory dermatoses such as seborrhoeic dermatitis, psoriasis or eczema, skin barrier function is less effective[3].

Chronic inflammation may lead to induration of skin and subcutis, and as in venous insufficiency, lipodermatosclerosis, where soluble and membrane-bound metalloproteinases favour enhanced turnover of the extracellular matrix in the lesional skin. However, in other circumstances, such as scleroderma, inflammation leads to atrophy of skin and underlying tissues.

Infection and colonisation

Normal human skin resists penetration by micro-organisms that routinely colonise its surface. Skin epidermal antimicrobial peptides and Langerhans cells are the most prominent factors in the defensive responses. Two major classes of dermal peptides, cathelicidins and β-defensins expressing antibacterial activity, are produced by keratinocytes. Moist lesions where the epidermal barrier is disrupted by dermatological disease like atopic dermatitis, are readily colonised by Staphlococcus aureus. Adherence to epithelia and numbers of organisms correlate with the severity of the eczema.

Infection itself is a cause of acute and chronic inflammatory reactions and in lymphoedema in particular, patients may suffer from recurrent bouts of cellulitis. This causes particular problems for healing, so appropriate treatment must be sought. An erosive pustular dermatosis is generally ascribed to fungal infection of the skin under the moist and warm microenvironment induced by sustained multilayer bandaging.

The effect of lymphoedema on the skin

Chronic disturbance of lymph flow results in chronic inflammation in the swollen body parts with enhanced activity and proliferation of cells contained in the epidermis, underlying dermis including vessels, and fat tissue. The clinical signs resulting from these alterations are:

- thickening of the skin and of all underlying tissues (fat, connective tissue, fascia)
- hyperkeratosis
- papillomatosis
- hyperpigmentation
- fibrosis with loss of skin suppleness
- deepening of the skin folds

Papillomatosis: Papillomatosis produces firm raised projections on the skin due to dilation of lymphatic vessels and fibrosis, and may be accompanied by hyperkeratosis *(Figures 2 and 3)*.

Figure 2a-b: Papillomatosis

Figure 2a

Figure 2b

Figure 3 a-b: Severe papillomatosis

Figure 3a

Figure 3b

Sometimes dilated lymph vessels can be found which may form cystic 'vesicles' leading to lymphorrhoea and fistulisation following rupture. In mixed (arterio-venous) lymphatic malformations and in congenital disorders such as Klippel-Trenaunay syndrome, true lymphangiomas can be seen.

Skin is actively maintained in homeostasis by a dynamic repair response after perturbation, through epidermal hyperplasia and inflammation aimed at restoring its unique properties and integrity. In lymphoedema, the skin's protective role may be compromised by impairment of the innate and adaptive immunologic defence against infection, and by perturbations of the skin barrier due to skin changes and/or due to external factors impacting on barrier homeostasis and structural integrity. The stratum corneum displays an 'acidic mantle' with a pH gradient across the intercellular spaces of the epidermis, and this acidification is required for barrier homeostasis. Perturbation of the pH will delay barrier recovery and facilitate inflammation and infection[4].

Innervation: Innervation of the skin mediates the sensations of heat, cold, itch, touch and pain, and co-regulates the functions of all types of small vessels, sweat glands and the pilosebaceous units. Peripheral neuropathy may thus directly and indirectly influence blood and lymphatic flow, the formation of the protective mantle, recognition of and response to external noxes, including the capacity to modulate the immune responsiveness of the epidermal cells. Paralysed limbs often develop chronic oedema through the combined effects of hyperaemia, gravity, loss of lympho-venous pump and immobility.

Dry skin: Dry skin develops when alterations of the stratum corneum barrier lead to a loss of water, lipids or the natural moisturising factor (NMF) of the epidermis. The wicking effect of bandages may aggravate this, making the skin less pliable and elastic and prone to cracks and fissures. Dry skin *(Figure 4)* may vary from slightly dry or flaky to rough and scaly. Patients may complain of itching.

Figure 4: Rough and scaly dry skin

The xerotic skin is dry, dull, covered with fine scales and feels rough. Barrier perturbation, mechanical factors (scratching the itchy skin), and application of irritant substances further delay recovery and lead to release of pro-inflammatory cytokines. In more advanced stages the skin may become dull red, oozing, crusting, excoriated and presenting nummular lesions of asteatotic eczema or irritant dermatitis.

Hyperkeratosis:
Hyperkeratosis is caused by over-proliferation of the keratin layer and produces scaly brown or grey patches *(Figure 5)*. It relates to mechanical trauma, for example, repeated low grade friction and repetitive mechanical trauma in suboptimal footwear (open heels, 'slippers') and under compression bandages at pressure sites. It must be distinguished from acanthosis nigricans in endocrinopathies like morbid obesity and the metabolic syndrome.

Figure 5: Hyperkeratosis

Figure 6: Lymphangiectasia

Figure 7: Lymphorrhoea with associated maceration

Figure 8: Fungal infection

Figure 9: Folliculitis

Figure 10a-b: Contact dermatitis

Figure 10a

Figure 10b

Lymphangiectasia: Lymphangiectasia or lymphangiomata, are soft, fluid-filled projections caused by dilatation of lymphatic vessels *(Figure 6)*. Lymphatic protruding dilatations and cysts may rupture under the mechanical burdens of manual drainage or compression bandaging, resulting in lymph leakage (lymphorrhoea) *(Figure 7)*.

Maceration: In deep skin folds, occluded skin sites, and around areas with lymph leakage, the skin frequently becomes wet and macerated, losing its defence against infection, and allowing easy penetration of applied substances/allergens. An over-hydrated epidermis is more susceptible to blistering and breakdown.

Infection: Fungal and bacterial infections can develop, since defence is impaired in several ways, for example, a break in the skin, blockage or malfunctioning of drainage routes and lymph node alterations. Intertriginous infections may be caused by yeast, microbes, and fungi. Fungal infection *(Figure 8)* occurs in skin creases and on skin surfaces that touch. It causes a moist, whitish exudate and itching, and is particularly common between the toes. It can lead to the development of cellulitis/erysipelas. Tinea pedis frequently accompanies a fungal infection elsewhere e.g. in the groin.

Folliculitis *(Figure 9)* is due to inflammation of the hair follicles. It causes a red rash with pimples or pustules, and is most commonly seen on hairy areas (head, trunk, buttocks, limbs). It favours areas that are occluded. The cause is usually *Staphylococcus aureus*, and it may precede cellulitis/erysipelas. In some cases, named irritant folliculitis, it will be non-infectious but elicited by friction (compression treatment), or due to the application of occlusive substances, like petrolatum or lipophilic topical preparations. Application of ointments in a direction opposite that of hair growth may exacerbate these follicular lesions. Fungi (dermatophytes, *T. rubrum*) may induce folliculitis on the legs, called Majocchi's granuloma. Surrounding areas of intertriginous candidiasis, pruritic pustules may be seen which are caused by candida species, and facilitated by the use of antibiotics and corticosteroids.

Contact dermatitis: When applying topical medication, skin care products, or through occupational exposure, people suffering from chronic oedema (especially in venous disease) and lymphoedema are at risk of developing allergic or cumulative irritant contact dermatitis. Signs may include itchy or painful fissures, dessication, erythema and even vesicles, but predominantly lichenification and hyperkeratosis. Irritant contact dermatitis is a multifactorial syndrome; barrier status of the skin, environmental 'climate', incontinence or poor hygiene, and exposure to detergents and cleansers, alcohols, oils, and even prolonged immersion in water may be the precipitating causes. Contact dermatitis *(Figure 10)* is the result of an allergic or irritant reaction. It usually starts at the site of contact with the causative material, but may spread. The skin becomes red, itchy and scaly, and may weep or crust. If contact allergy is suspected, contact allergy tests must be performed to indicate the allergen to be avoided: topical products including medication like corticosteroids, antiseptics, perfumes, additives, constituents of dressings or compression devices.

Venous eczema: Also known as varicose eczema or stasis dermatitis, usually occurs on the lower legs *(Figure 11)*, particularly around the ankles, and is associated with varicose veins. The skin becomes pigmented, inflamed, scaly and itchy. People suffering from venous eczema are very much at risk for developing allergic contact dermatitis and thus topical treatment should avoid potential allergens if at all possible.

Ulceration: Ulceration is unusual in primary lymphoedema patients; in most cases it is to be attributed to trauma or comorbidities/underlying diseases. It is important to establish the underlying cause of the ulcer because it determines treatment and whether compression is appropriate *(Figure 12)*.

Skin tumours related to lymphedema

Lymphangiosarcoma: In the most severe cases of lymphoedema, lymphangiosarcoma, a rare form of lymphatic cancer (Stewart-Treves syndrome) can develop *(Figure 13)*. It mainly occurs in patients who have been treated for breast cancer with mastectomy and/or radiotherapy. The sarcoma first appears as a reddish or purplish discoloration or as a bruised area that does not change colour. It progresses to an ulcer with crusting, and eventually to extensive necrosis of the skin and subcutaneous tissue. It can metastasise widely.

Skin Care

Maintenance of skin integrity and careful management of skin problems in patients with lymphoedema are important to minimise the risk of infection.

The general principles of skin care include:

- washing daily, using pH neutral soap, natural soap or a soap substitute, drying thoroughly
- if skin folds are present, ensuring that they are clean and dry, monitoring the affected and unaffected skin for cuts, abrasions or insect bites
- applying emollients
- avoiding scented products
- using vegetable-based products rather than those containing petrolatum or mineral oils in tropical climates

The aim is to preserve skin barrier function through washing and the use of emollients[5]. Ordinary true soaps, which usually

Figure 11 a-b: Venous eczema

Figure 11a

Figure 11b

Figure 12: Ulceration

Figure 13: Stewart-Treves syndrome (lymphangiosarcoma)

contain detergents and have an alkaline pH of 9-10, should be avoided because they tend to dry the skin. Natural or pH neutral soap can be used. Synthetic detergents (syndet cleansers, bar or liquid) have a pH of 5.5-7 in order to minimise skin barrier disruption. They are also called 'soap-free soap'. Body wash emulsion systems combine a syndet with moisturisers or emollients. Lipid-free cleansers may contain glycerin and other emollients, while cleansing creams contain waxes and mineral oil. Transparent soap has glycerin and sucrose added. The perfumes and preservatives in scented products may be irritant or allergenic. Cleansing ability of soaps is in direct proportion with skin barrier disruption; therefore we recommend using moisturisers after cleansing the skin in order to replace the lipid film barrier that has been disrupted by washing.

Emollients re-establish the skin's protective lipid layer, preventing further water loss and protecting the skin from bacteria and irritants. Emollients can be bath oils, or moisturisers (lotions, creams and ointments). In general, ointments, which contain little or no water, are better skin hydrators than creams, which are better than lotions. In high concentrations, mineral oil based products may exacerbate dry skin conditions by occluding skin pores, hair follicles, and preventing natural barrier repair mechanisms. Petrolatum allows barrier repair while permeating throughout the interstices of the stratum corneum. Humectants are substances like glycerin, honey, sodium lactate and urea that attract moisture (from the epidermis) and need to be combined with occlusive emollients to keep the water on the surface. They help to improve smoothness of xerotic skin by inducing corneocyte swelling.

The best method of emollient application is unknown. Some practitioners recommend applying them using strokes in the direction of hair growth (that is, towards the feet when applying to the legs) to prevent blockage of hair follicles and folliculitis. Others recommend applying emollients by stroking towards the trunk to encourage lymph drainage.

Skin care regimens

Skin conditions that can occur in patients with lymphoedema require careful management *(Figure 14)*. They may occur simultaneously and require combinations of regimens. The general principles of skin care apply to all conditions *(Box 1)*.

Intact skin: The condition of intact skin should be optimised by applying emollient at night.

Dry skin: Emollients should be applied twice daily (including after washing) to aid rehydration. If the heels are deeply cracked, emollients and hydrocolloid dressings may help and the patient should be referred according to local dermatology guidelines.

Figure 14: Skin changes

Hyperkeratosis: Frictional and mechanical causes need to be recognized and remediated: footwear, bandages, rubbing and scratching. Many of the frequent nail changes are due to repeated trauma: onycholysis, subungual haematoma, hyperkeratosis, paronychia.

Emollients with low water content are recommended. MLLB reduces the underlying lymphoedema and improves skin condition. If the condition has not improved within two weeks, the patient should be referred according to local dermatology guidelines.

Papillomatosis: The condition may be reversible with adequate compression. If the condition does not improve after one month, the patient should be referred to a lymphoedema service.

Contact dermatitis: Avoidance of causative irritants and allergens is the primary treatment for irritant and allergic contact dermatitis. The goal of treatment is to restore epidermal barrier function. For irritant dermatitis this entails substitution of offending products and/or habits, emollients, and preventive skin protection. Topical corticosteroids are frequently used, but their efficacy in irritant dermatitis is controversial: their use should be limited to a few days. Acute episodes of contact allergic dermatitis are treated with a potent topical corticosteroid in ointment form, for example, clobetasol propionate 0.05% or betamethasone dipropionate 0.05%, once or twice daily. After seven days, treatment should be reviewed. If the condition has improved, a moderate strength corticosteroid can be substituted, for example, clobetasone butyrate 0.05% or betamethasone valerate 0.12%. Treatment should continue for three to four weeks, during which time the strength of the steroid and amount applied are gradually reduced. The patient should be referred according to local dermatology guidelines if the condition does not improve.

Venous eczema: Adequate compression treatment is expected to reverse the secondary skin changes seen in venous insufficiency including venous eczema. Treatment is with topical corticosteroids in ointment form as recommended in local guidelines, e.g a potent corticosteroid such as betamethasone dipropionate 0.05% with clioquinol 3% for seven days, followed by a moderate corticosteroid such as betamethasone valerate 0.1%, or Triamcinolone acetonide 0.1%. A non-sensitising, low water content emollient should be applied during steroid treatment. If ABPI is <0.5, the patient should be referred to a vascular surgeon. The patient should be referred according to local dermatology guidelines if the condition persists.

Ulceration: If venous and/or arterial disease is present, the internationally agreed leg ulcer management algorithm should be followed. The ulcer will require an appropriate dressing and the surrounding skin will need to be treated according to its condition. Exercise/movement and optimal nutrition should be encouraged and long periods of limb dependency minimised. The patient should be referred to the appropriate specialist service if the ulcer is unresponsive after six to eight weeks, or if there is rapid deterioration or a drop in ankle brachial pressure index (ABPI).

Lymphangiectasia: Treatment is compression with LCB. If there is no response to initial compression or the lymphangiectasia are very large, contain chyle or cause lymphorrhoea, the patient should be referred immediately to a lymphoedema practitioner with training at specialist level.

Lymphorrhoea: The patient may require medical review to determine the underlying cause, e.g worsening congestive heart failure. The surrounding skin should be protected with emollient, and non-adherent absorbent dressings should be applied to the weeping skin. LCB will reduce the underlying lymphoedema, but needs to be changed frequently to avoid maceration of the skin. Frequency of change will be determined by factors such as strikethrough and the rate of swelling reduction. In the palliative situation, light bandaging may be more appropriate. If the condition does not improve with six weeks of treatment, the patient should be referred to the lymphoedema service.

Lymphangiosarcoma: Patients with suspected lymphangiosarcoma require urgent referral to an oncologist.

Folliculitis: Swabs should be taken for culture if there is any exudate or an open wound. An antiseptic wash/lotion, e.g one containing chlorhexidine and benzalkonium, should be used after washing. Emollient should be applied without being rubbed in. If there is no response after one month, the patient should be referred according to local dermatology guidelines.

Fungal infection: Skin scrapings and, if nails are affected, nail clippings should be sent for mycological examination. Treatment is with terbinafine 1% cream for up to six weeks alongside meticulous skin care. In some countries, Whitfield ointment is used as an alternative. Any sign of bacterial infection should be treated promptly (see management of cellulitis/erysipelas). Nail infection and fungal folliculitis require treatment with an oral antifungal agent under medical supervision. The patient should be referred to a dermatologist if there is no response after six weeks' treatment. Colonised / infected foot wear is a frequent source of recurrent skin and nail infection.

Cellulitis/erysipelas

Patients with lymphoedema are at increased risk of acute cellulitis/erysipelas, an infection of the skin and subcutaneous tissues. The cause of most episodes is believed to be Group A haemolytic streptococci.

Symptoms are variable. Episodes may come on over minutes, grumble over several weeks or be preceded by systemic upset. Symptoms include pain, swelling, warmth, redness, lymphangitis, lymphadenitis and sometimes blistering of the affected part *(Figure 15)*. More severe cases have a greater degree of systemic upset, e.g. chills, rigor, high fever, headache and vomiting. In rare cases, these symptoms may be indicative of necrotising fasciitis.

Figure 15: Cellulitis

The focus of the infection may be tinea pedis (athlete's foot), venous eczema, ulceration, in-growing toe nails, scratches from plants or pets, or insect bites. Box 1 outlines the principles involved in the management of acute cellulitis/erysipelas at home or in hospital.

It is essential that patients with cellulitis/erysipelas, who are managed at home, are monitored closely, ideally by the general practitioner. Prompt treatment is essential to prevent further damage that can predispose to recurrent attacks.

Box 1: Guidelines for the management of cellulitis/erysipelas in lymphoedema[6] - (Adapted from the Best Practice for the Management of Lymphoedema. International consensus document, with kind permission of MEP Ltd)

Exclude:

- Other infections, for example, those with a systemic component
- Venous eczema, contact dermatitis, intertrigo, microtrauma and fungal infection
- Acute deep vein thrombosis
- Thrombophlebitis
- Acute lipodermatosclerosis
- lymphangiosarcoma (Stewart-Treves syndrome)

Swab any exudate or likely source of infection, for example, cuts or breaks in the skin
Before starting antibiotics establish:

- The extent and severity of the rash – mark and date the edge of the erythema
- Presence and location of any swollen and painful regional lymph nodes
- Degree of systemic upset
- Erythrocyte sedimentation rate (ESR) or C-reactive protein (CRP) and white cell count

Start antibiotics as soon as possible, taking into account swab results and bacterial sensitivities when appropriate.

- During bed rest, elevate the limb, administer appropriate analgesia (for example, paracetamol or non-steroidal anti-inflammatory drugs (NSAID), increase fluid intake
- Avoid simple lymphatic drainage (SLD) and manual lymphatic drainage (MLD)
- If tolerated, continue compression at a reduced level or switch from compression garments to reduced pressure MLLB
- Avoid long periods without compression
- Recommence usual compression and levels of activity once pain and inflammation are sufficiently reduced for the patient to tolerate
- Educate patient/carer – symptoms, when to seek medical attention, risk factors, antibiotics 'in case', prophylaxis if indicated

Criteria for hospital admission

The patient should be admitted to hospital if they show:

- signs of septicaemia (hypotension, tachycardia, severe pyrexia, confusion or vomiting)
- continuing or deteriorating systemic signs, with or without deteriorating local signs, after 48 hours of oral antibiotics
- unresolving or deteriorating local signs, with or without systemic signs, despite trials of first and second line oral antibiotics.

References

1. Cork MJ. (1997) The importance of skin barrier function. *J Derm Treat.* 8: S7-13
2. Proksch E, Brandner JM, Jensen JM. (2008) The skin: an indispensable barrier. *Exp Dermatol.* 17 (12): 1063-72
3. Flour M. (2009) The pathophysiology of vulnerable skin. *World Wide Wounds.* http://www.worldwidewounds.com/2009/September/Flour/vulnerable-skin-1.html
4. Schmid-Wendtner MH, Korting HC. (2006) The pH of the skin surface and its impact on the barrier function. *Skin Pharmacol Physio.* 19 (6): 296-302
5. Korting HC, Kober M, Mueller M, et al. (1987) Influence of repeated washings with soap and synthetic detergents on pH and resident flora of the skin of forehead and forearm. Results of a cross over trial in healthy probationers. *Acta Derm Venereol.* 67 (1): 41-7
6. Partsch H. (2003) Understanding the pathophysiological effects of compression. In: European Wound Management Association *(EWMA). Position Document: Understanding compression therapy.* MEP Ltd, London

CHAPTER 6
Adapting compression bandaging for the palliative patient

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Background
Care of the lymphoedema patient with advanced malignant disease requires modified treatment approaches and redefinition of the goals of care.

The key palliative care concepts relating to lymphoedema include:

- understanding and respect for the uniqueness of the patient
- family centred lymphoedema care
- interdisciplinary teamwork
- communication with the patient, family and other palliative care providers
- pain and symptom control
- maintenance of independence and function
- managing patient fears and expectations

Lymphoedema in advanced cancer
In patients with advanced cancer, oedema is often multifactorial and may increase as the disease progresses[1,2] *(Box 1)*. It is important to determine if the oedema is multifactorial as this will impact treatment decisions[3-5]. This is often the case with leg oedema, where there may be concurrent hypoalbuminaemia or venous compression.

Box 1: Possible causes of oedema in palliative patients

- Malignancy infiltrating or compressing lymphatic structures
- Venous obstruction (thrombosis, compression by tumour)
- Decreased albumin (anorexia/cachexia; ascites with repeated paracentesis)
- Renal, cardiac or hepatic failure
- Dependent limb; immobility; neurological deficit
- Side-effects of chemotherapy, steroids, nonsteroidal inflammatory drugs, bisphosphonates
- Infection

Malignant lymphoedema is caused by actual tumour involvement of lymphatic vessels or nodes. Sometimes the lymphoedema in a limb is not malignant, but the previously well-managed lymphoedema patient may have developed an advanced life-threatening illness that is impacting on function or is causing other symptoms such as pain *(Figure 1)*. The treatment guidelines below also apply for benign lymphoedema in the palliative patient.

Figure 1 a-b: Advanced lymphoedema secondary to breast cancer

Figure 1a

Figure 1b

Benefits of oedema management

Lymphoedema therapy can be comforting and healing at the end of life, even when prognosis is poor; active participation in treatment may provide patients and family with a focus of care. While in the presence of irreversible co-existing medical conditions lymphoedema treatment results are poor, it may be a comfort to patient and family to know that they are not being 'abandoned'[1]. Early family caregiver involvement is helpful since the patient may not be able to self-manage because of fatigue, weakness, dyspnoea or other issues that may impact function. In all cases, reduction of pain, minimising infection, skin care and psychological support are key[6].

Indications for the use of compression palliative bandaging

Any lymphoedema that is more than mild (defined as greater than 20% volume difference between limbs) is an indication for compression bandaging[7]. Palliative care patients do not tolerate elastic compression garments well due to the high resting pressures, or because the limb deformity causes constriction or a tourniquet effect. Even flat-knit garments may be difficult to fit, and therefore modified multilayer bandaging is often the best compression option[5].

International consensus affirms the palliative benefits of oedema reduction in the presence of active tumour[8]. In the presence of malignant lymphoedema it is indicated to start or continue compression bandaging unless a standard contraindication exists *(Table 1)*. In general, multilayer bandaging will help reduce oedema and pain, will prevent lymphorrhoea and will help preserve or regain limb function[5,9]. However, in spite of one's best efforts, there may be limited success with bandaging in patients with malignant lymphoedema. Sometimes only oncologic treatment of the tumour with palliative chemotherapy or with radiotherapy will lead to significant control of the oedema[9].

Compression therapy may be ineffective in severe hypoalbuminaemia with generalised oedema. Although the combination of lymphoedema and hypoalbuminaemia is not a contraindication to compression bandaging, this kind of multifactorial oedema may be more of a challenge to treat and lymphorrhoea may occur more easily[5].

Cautions

The cause of the oedema will determine whether compression is indicated, although practitioners should be aware of conditions where it should be used with caution *(Table 1)*. In palliative patients particularly, it is wiser to obtain medical advice before applying any new compression treatment. For example, with deep venous thrombosis (DVT) the use of compression and exercise may dislodge the clot causing a pulmonary embolism[10]; however, withholding compression could lead to lymphorrhoea. In such cases, the practitioner and patient should review the personal goals of care – prolonging life or comfort and quality – and discuss with appropriate health care providers whether or not the cause can be treated or drugs (for example, non-steroidal inflammatory drugs, bisphosphonates) withdrawn[3]. Compression should be used with caution, and regular assessment undertaken where decreased sensation or numbness is present[11].

Table 1: Conditions contraindicating or requiring adaptation of treatment

	Compression bandaging
Absolute contra-indications	Acute deep venous thrombosis in the affected limb
	Severe neuropathic pain
	Severe bone pain
	Acute congestive heart failure
	Decreased sensation, numbness in affected limb (for example, spinal cord compression, brain metastases)
	Severe peripheral vascular disease
Adapted technique, reduced compression and surveillance	Diabetes
	Poor arterial supply to limb (ratio of posterior tibial to brachial artery pressure 0.5-0.8)

Redefining aims of treatment

At any stage in the palliative care journey, the ability to tolerate compression may diminish or oedema reduction becomes a less important goal; this may necessitate a redefinition of the aims of care and associated therapeutic input by the patient, therapist and physician[5,9,11,12]. It is important that the treatment modality not be burdensome compared to the benefits that are achievable. Regular communication among the interdisciplinary team, patient and family will help ensure the most appropriate treatment. It is usually not possible to achieve major reduction and normal limb contour even if the oedema is soft and pitting. One needs to redefine therapeutic success, to reduce expectations as regards oedema reduction and aim for:

- containment of the oedema, preventing it from becoming worse
- prevention of lymphorrhoea and wounds
- pain reduction
- improvement of joint mobility and maximising quality of life

Redefining outcome measures

Since the degree of oedema may vary from day to day, circumferential measurements may not be useful as a monitor of treatment success[9]. Rather, general measures of function and ability to participate in activities of daily living that involve the affected limb(s) may be more appropriate: for example, being able to feed oneself, or to lift one's legs onto the bed by oneself[9]. In terms of guiding treatment, one could also monitor patient and family satisfaction and involvement with lymphoedema care.

How traditional methods of bandaging are adapted in palliative care

Degree of compression and bandage types

Compression pressure may need to be reduced as patients are often unable to tolerate pressure[4,11] because of pain or sensitive skin. This is most easily accomplished by reducing the number of bandage layers or by using specially shaped tubigrip. One should 'start low and go slow', in terms of degree of compression[5]. In general, a low resting pressure is better tolerated, so use short-stretch bandages. However, if flaccid paralysis is present, medium stretch or long stretch components may be helpful in reducing oedema[5]. A combination of short and long stretch bandages may also be useful in conditions such as mixed oedemas[9,11]. In patients with marked lower extremity lymphoedema, bandage the lower leg initially, then full leg *(Table 2)*.

Bandaging times

The oedema in palliative cases may rapidly re-accumulate unless continuous, 24-hour per day compression is applied. However, bandaging layers should be removed and reapplied daily or at most, every 2 days and skin condition assessed and recorded. This is because[5]:

- the skin of the palliative patient may be very friable, and we need to ensure that we are not compromising skin integrity

Table 2: Some issues when using compression bandaging in palliative care

Issues	Possible solutions
Unclear diagnosis of cause of oedema	Investigate for multiple causes and treat accordingly
Unclear aims of care	Assess frequently, determine realistic goals and communicate these to the patient and family
Compression poorly tolerated	Reduce compression layers or tension
Risk of proximal oedema	Reduce compression or bandage the proximal limb only
Genital oedema (male)	Close-fitting shorts with Lycra to provide scrotal support Scrotal bandaging Teach SLD
Genital oedema (female)	Lycra shorts with anatomically contoured foam pads Teach SLD
Lymphorrhoea	Control with absorptive layers and compression
Open wounds	Appropriate wound care products and multilayer bandaging unless contraindicated by medical treating team Wounds can be painful; reduce direct pressure with shaped foams
Difficulty fitting or tolerating elastic garments	Use low stretch multilayer bandages
Pain or sensitive skin (allodynia)	Reduce compression, more aggressive pain management Change protective first layer – try an alternative product
Rapidly reaccumulating oedema	Increase length of time under compression
Cannot use traditional assessment and measurement tools to monitor success of therapy	Monitor, function, quality of life, patient and family satisfaction

- skin sensation may be reduced, in which case compression must be more closely monitored
- the oedema may be soft and reduce quickly, rendering the bandages too loose

Padding layers

Preserving skin integrity may be a challenge in the palliative patient who may have compromised nutrition. Extra padding using cut-out foam pieces at vulnerable areas may need to be added. Open cell foam under-padding may help hold bandages secure. This softer kind of foam is well tolerated when skin is sensitive. Consider using less cumbersome, alternative padding layers (for example, light felt, cellona, other soft padding, etc.) to facilitate better mobility within the bandage[5,9]. The therapist can tailor the foam layers so that family caregivers can more easily apply the under-padding themselves. If they have trouble with this, commercially available fitted foam sleeves over which the family member can bandage may be helpful.

Dealing with proximal oedema

Proximal trunk oedema may be a particular problem in palliative patients[5]. If proximal oedema increases, one may have to reduce compression pressure, and add or increase manual lymph drainage or simple lymphatic drainage manoeuvres. For arms, one technique is to alternate bandaging fingers to elbow and fingers to axilla. In lower extremity lymphoedema bandaging has the potential to increase genital or truncal oedema[9]. Here it may be prudent to begin bandaging only the lower leg, then progressing to full leg bandages, or full leg, alternating with half leg, daily[5]. Patients with severe lymphorrhoea may benefit from lower leg bandaging despite the proximal swelling caused.

Lycra-type shorts may help prevent or control groin and genital oedema. After consultation with the treating physician, compression bandaging may be applied over wounds and wound dressings.

Managing lymphorrhoea and wounds

Multilayer bandaging will usually control lymphorrhoea[5]. In patients with severe lymphorrhoea one has to balance the risks: lower leg bandaging may be very helpful but there is the risk of causing proximal swelling. Until lymphorrhoea is controlled, absorptive layers such as abdominal or incontinence pads, will be required under the bandages, with the bandages being reapplied as necessary, often more than once daily at first. Wounds may be handled in the same way, with appropriate wound dressings as the first layer. The therapist must work with the treating team to ensure that compression over the particular wound or wounds can be initiated and that there is no specific contraindication.

Physiotherapy, exercise, positioning

Concurrent physiotherapy to help maintain muscle strength and tone will also help lymphatic drainage[7]. Gentle exercise while wearing compression can help reduce oedema. In advanced palliative patients, there may be positioning issues, either because of pain or weakness. The therapist must take these factors into consideration and ensure that the patient is comfortable during the bandaging and subsequently.

Subcutaneous drainage

The use of subcutaneous drainage techniques[13,14], using needles that drain into enclosed bags, merits further research as a technique that could be combined with compressive bandaging.

Controlling other symptoms

Appropriate and impeccable pain and symptom control may not only make the patient more comfortable but will enable them to better tolerate compression bandaging. Therefore, patients should whenever possible be managed with team members who are able to control symptoms such as pain, nausea, vomiting, and dyspnoea. Nutritional support is important to help maintain stamina, function and skin integrity.

Treatment and control of depression and/or anxiety with appropriate psychosocial support and medication, if required, will also help the oedema management by improving the patient's tolerance of compression treatment.

There is sometimes concern about the use of steroids in the setting of chronic oedema and advanced cancer. Potent steroids such as dexamethasone are useful and are commonly used in patients with a limited prognosis to control a variety of symptoms and they are often an adjuvant in chemotherapy regimens. If the steroids help control symptoms as well as reducing tumour mass then they can help manage lymphedema. Less commonly, long-term steroid use will actually make the oedema worse. If this is the case, the oncologist or palliative care team may need to find an alternative treatment.

Conclusion

Care of lymphoedema in the palliative care patient is guided by their physical and psychological needs. Practitioners can adapt standard therapies to meet these needs, and provide a positive therapeutic input on a number of levels through creative strategies and close interdisciplinary work.

References

1. Cheville A. (2002) Lymphedema and palliative care. *Lymphlink.* 14: 104
2. Todd, M. (2009) Understanding lymphoedema in advanced disease in a palliative care setting. *Int J Pall Nurs.* 10 15 (10): 474, 476-80
3. Keeley V. (2000) Lymphedema. In: Twycross R, Jens K, Todd J. (Eds.) *Oedema in Advanced Cancer.* Radcliffe Medical Press, Oxford, UK
4. Williams AF. (2004) Understanding and managing lymphoedema in people with advanced cancer. *J Community Nursing.* 18 (11): 30
5. The International Lymphoedema Framework and Canadian Lymphedema Framework (2010). The management of lymphedema in advanced cancer and oedema at the end of life. http://www.lympho.org
6. Rymall C. (2003) Lymphedema therapy during adjuvant therapy for cancer. *Clin J Oncol Nurs.* 7: 449-451
7. Lymphoedema Framework. (2006) Best Practice for the Management of Lymphoedema. International consensus. MEP Ltd, London
8. Lymphology CDOT. (2009) The diagnosis and treatment of peripheral lymphoedema. *Lymphology.* 42: 51-60
9. Towers A, Hodgson P, Shay C, *et al.* (2010) Care of the palliative patient with cancer-related lymphedema. *Journal of Lymphedema,* 5 (1), 72-80
10. Shrubb D, Mason W. (2006) The management of deep vein thrombosis in lymphoedema: a review. *Br J Community Nurs.* 11: 292-297
11. Crooks S, Locke J, Walker, J, Keeley, V. (2007) Palliative bandaging in breast cancer-related arm oedema. *Journal of Lymphoedema.* 2 (1): 50-54
12. ALFP systematic review on palliative care and lymphedema (in press 2012)
13. Clein LJ, Pugachev E. (2004) Reduction of edema of lower extremities by subcutaneous controlled drainage: eight cases. *American Journal of Hospice and Palliative Care.,* 2 1 (3): 228-232.

CHAPTER 7

Compression therapy in Indian villages

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Preface

In developing countries, lymphatic filariasis (LF) is seen as the major cause of lymphoedema. The Global Alliance for the Elimination of Lymphatic Filariasis (GAELF) estimates that 16 million people suffer from lymphoedema due to LF[1]. However, the total number of patients with lymphoedema due to other causes in developing countries is unknown. In 1997, a resolution of the World Health Assembly (50-29)[2] initiated a programme for the elimination of lymphatic filariasis as a public-health problem. The disease represents a public-health problem because of its morbidity and the disabilities engendered by both the acute and chronic symptoms (lymphoedema and hydrocele). The prevention of disability in those who are infected represents the second pillar of the elimination programme.

In developed countries, it is possible to access massage and lymphatic drainage by healthcare professionals. In the majority of developing countries, only exercises undertaken by the patients themselves are possible. This chapter shows that lymphoedema compression in an emerging country is possible. This is a real encouragement; it highlights the good results obtained in reduction of lymphoedema severity, and shows how management constraints, such as the unavailability or high cost of materials, the lack of trained staff, the difficulty in getting regular access to healthcare facilities and the difficulty in carrying out regular patient follow-up, can be overcome.

The problem of regular patient follow-up is by far the most important as this can lead to unsuitable bandages being applied by the patient and incorrect lymphatic drainage, both of which can cause more harm than good.

We should remind ourselves that the main aim of lymphoedema patient management is to enable affected individuals to regain a better quality of life and social participation within their community. As Morgan[3] emphasised, the volume of lymphoedema does not necessarily correlate with an improvement in quality of life, thus we should always keep this in mind and implement activities adapted to the local situation, rather than focus on compression therapy.

The World Health Organization[1] recommends the use of minimal but efficient packages of measures for lymphoedema management due to lymphatic filariasis. This involves washing the entire limb carefully, paying specific attention to the hygiene of the inter-digital web and wounds, elevation of the affected limb during rest, work and at night, practicing simple exercises, mobilising the affected limb and wearing suitable shoes. The main goal of these basic interventions is to avoid occurrence of acute attacks, than a major factor of development of lymphoedema. At the same time, field experiences have shown that this minimum package could also have an impact on the grade of lymphoedema[4].

The basic principles for lymphoedema compression in developing countries depend on resources at country level. Each country could adapt the activities according to their available resources. When human and technical resources are available, complex physical therapy could be implemented, including manual lymphatic massage/drainage carried out by healthcare professionals and the wearing of compression garments.

Stout *et al*[5] present a basic care model for lymphoedema management indicating when compression therapy could be implemented. This model includes three levels (basic, intermediate and advanced) *(Box 1)*. The most important difference between these levels is the possibility of compression therapy implementation. This model fits the situation of developing countries.

The challenges for compression therapy implementation in developing countries are firstly to advocate for a reinforcement of its implementation in emerging countries as in India, Brazil and China and to use their experiences to extend to other developing countries; secondly, developing material for binding/compression giving priority for local production; thirdly to increase the number of trained staff for maximising the follow-up of patients.

Box 1: Basic care model for lymphoedema management[5] (reproduction and use with courtesy of Stout et al, 2011)

Level of Care	Elements	Assumptions	Goals
Basic	*Provider and patient education* Infection prevention Skin care Hygiene Mobility Elevation of the limb Wound care and wound prevention *Community interventions* Family and patient teaching Community support networks	Only basic knowledge of lymphoedema identification and treatment exists among medical providers and community. Resources are scarce.	Develop a network of community providers to enable education for lymphoedema identification and management Develop clinical interventions to support the basic care model (screening programs/ surveillance model of care) Promote home-based, patient centric care
Intermediate	Encompass basic model Educational models for health care providers and clinics Provider intervention is combined with a home based approach Provider intervention is routine and ongoing *Teach concepts of DLT, based on available resources*	Provider knowledge base exists but is not wide-spread. Some resources are present Community knowledge base is developing and growing National construct for intervention is supported	Develop a network of medical providers to enable surveillance for lymphoedema identification and management Develop clinical interventions that promote intervention at all levels of disease Promote patient centric care
Advanced	Encompass basic and intermediate models *Complete decongestive therapy is the standard of care* Resources are available for patients to receive goods and services warranted for their level of condition	Provider knowledge base is common. Community knowledge base is advanced; patients seek out levels of care appropriate to their level of involvement Providers engage in research initiatives	Patients manage complex therapies independently Advance the state of evidence based medicine regarding lymphoedema management Inform constructs for research and new innovations in industry
		More information on Lymphatic Filariasis is available from http://filariasis.org/	

Introduction

Indian villages harbour one third of the world's lymphatic filariasis disease burden. Lymphatic Filariasis (LF) is a mosquito-borne communicable disease, classified as a neglected disease of the poor by the WHO because there is little support for research and treatment[1]. The Global Alliance for the Elimination of LF (GAELF) has plans to achieve its goal of the elimination of LF by 2020[2]. However, these morbidity reduction plans are still in their infancy and there is no public health treatment programme.

However, in India, the Institute of Applied Dermatology (IAD) (http://www.iad.org.in/) developed an integrative treatment combining the benefits of western biomedicine and the traditional Indian practice of Ayurveda and yoga to treat large numbers of lymphoedema patients in Indian villages. Compression bandaging is part of IAD's integrative treatment of lymphoedema.

Materials used for compression

1. Long-stretch bandage: available in three sizes
2. Finger bandage: stretching cloth without rubber 6cm width and 2½ meter in length for grade 2 lymphoedema, and long stretch elastic rubber knitted bandages 6cm width and 2½ meter in length for grade 3 lymphoedema
3. Cotton cloth
4. Cold cure foam (CCF) sheet
5. Microcellular rubber (MCR) sheet
6. Chalky bags and moulds
7. Sandwich mould
8. Inelastic bandage (when available, usually if donated from abroad)

Preparation before compression

a. CCF sheet: is cut into long pieces to cover the limb; the length and width is determined by the size of the limb (limb girth measurements). Three such pieces are needed for each limb.

   Two application methods are used:

   One piece - The limb is covered with single piece of CCF. This method is used when the swelling is spherical and limited below knee.

   Two pieces - This method is used when oedema extends up to groin and there is less oedema in knee region giving an hour glass appearance. One long piece of CCF is placed on anterior side of the limb and a second piece placed over posterior side. As the limb size reduces, we reduce the breadth of the CCF. CCF (proportional in measurement to the girth of mid thigh) is placed over the thigh region from slightly above the mid thigh to knee. A second piece of CCF, cut to accommodate the measurement of maximum bulk at calf, is placed around the leg from shin to ankle. The pressure should be less in upper segment. This method avoids constriction at knee level.

b. Chalky bag: the remaining cut sheets of CCF are made into small pieces, placed into the cotton stockinet and tied at both ends (*Figure 1*).

c. Sandwich mould: this is prepared using smaller sheets covered with cloth; the thickness of the mould depends on the width of skin crevasses to be separated.

d. MCR moulds: are prepared by cutting micro-cellular rubber sheets into required size and carving oblique diamond-shaped grooves using a scalpel.

Figure 1 a-d: Locally available materials used during compression therapy

1a: *Chalky bag*
1b: *Sandwich moulds*
1c: *CCF pieces*
1d: *MCR mould*

Routine procedure

Various procedures are employed to achieve effective compression for different clinical presentations (*Table 1*). These will be outlined more fully through this chapter.

Toe compression

Oedematous toes are covered with gauze or bandage material after performing 'part 2' of Indian Manual Lymph Drainage using Ayurvedic oil[6]. Initially, the bandage is rolled clockwise around the metatarsal region twice, then rolled over the great toe and back over the metatarsal region[7]. This procedure is repeated for the four medial toes, but not the little toe. Toe bandaging prevents shifting of oedema from foot to toe.

Table 1: Compression procedures

Steps of compression	Position	Techniques of compression
Toe compression	Lying position	Figure-of-eight, spiral and double layer
Cotton cloth wrapping	*Bhekasna* position	Half compression
Mould placing (de-kinking/ sponge moulding)	Straight leg rising position	Full compression
Compression with long stretch bandage	Standing position	Half and half compression

Cotton cloth wrapping

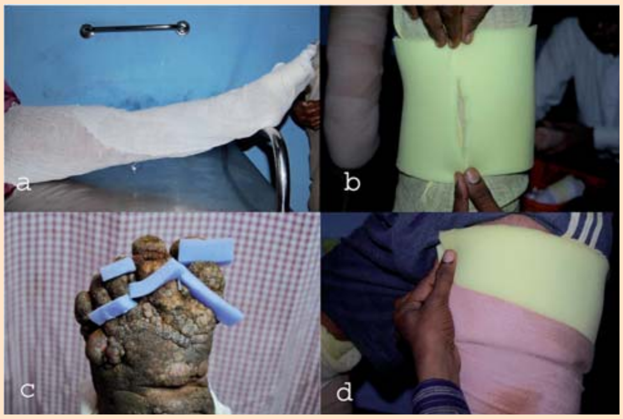
After toe compression, the limb is wrapped up to the level of oedema[5]. Sterilised (in a pressure cooker or similar) starch-free cotton cloth is cut according to the size of the limb. For patients undertaking self bandaging, a ribbed, cotton stockinet (available in differing diameters) is used as it is easier to pull over limb. Size is selected according to the thigh measurement. Cotton cloth wrapping prevents the direct contact of oil with the compression bandage *(Figure 2)* and the friction and sweat associated with long-stretch bandages.

Sponge moulds

Moulds are used to avoid constriction due to the rolling back or slipping of bandages into crevasses. These moulds separate skin folds to achieve free drainage of lymph and to cylindrical compression. Following oil massage, the limb is covered by cotton cloth. Moulds, usually used from day three of treatment onwards, are used to even out folds and achieve a uniform limb shape. When skin folds measure over 50cm in circumference, chalky bags or sandwich moulds are used in order to separate the crevasses. In certain folds, CCF pieces are placed above sandwich moulds to get a uniform surface for compression bandaging *(Figure 2b)*. Long-stretch compression material is wrapped over the moulds in a figure-of-eight. If more pressure is required, moulds are placed under long stretch bandages.

Mould placing helps free flow of lymph by (possibly) de-kinking the lymphatic channels. A separated fold is kept dry due to moisture evaporation, thus reducing the potential for fungal infection. The outer surface of the chalky bag is irregular and creates a wavy surface of compressed skin, thus facilitating free lymph flow.

Figure 2a -d:



***2a:** Cotton cloth wrapping soaks up remaining oil and absorbs sweat*

***2b:** CCF pieces placed to achieve a uniform surface*

***2c:** Rectangular CCF sheets are used for additional pressure*

***2d:** Narrow sheets of CCF placed below the upper end of bandage helps roll back and prevents constriction*

The CCF sheet density is either 23 or 15mm, and is available in a variety of sizes and shapes to match those seen in lymphatic filariasis limbs. Spherical or half moon sheets are use for metatarsals, rectangular for shins and bean-shaped to drain oedema behind malleoli. CCF moulds are generally used over ankle knee and thigh regions *(Figure 2c)* as these have greater mobility and maximum chance of constriction. The sponge moulds avoid constriction[8], keep the limb cylindrical and provide equal pressure as in other areas. A rectangular CCF sheet is placed around the thigh at the upper part of the bandage to avoid slipping/rolling of the bandage *(Figure 2d)*.

Preparation of MCR moulds

A piece of MCR sheet is cut to the required size and diamond shaped grooves carved are on the inner surface to facilitate greater pressure and lymph flow. The MCR of the required shape is taken, and oblique grooves created using a scalpel. The edges of MCR are blunted to avoid excoriation.

Compression bandages

Long-stretch bandages

The bandage is made up of cotton and rubber thread which has 300% extensibility and 100% elasticity. Bandages are expensive and durability is about 2 weeks *(Table 2)*. Although products manufactured by over 30 companies are available in the market, only Dynamic techno products meet the basic minimum quality of 140% stretch.

Table 2: Overview of compression materials and wear-time

Material	Durability	Disinfection method(s)	Cost per unit (Indian rupees)
Toe bandages, long stretch finger bandage (Soft touch hygiene products and Carminal medi tech)	Reused for three days. Long stretch toe bandages can be reused for a month	Washed, ironed or dried. Stretch bandages are disinfected in the same way as long stretch compression bandages	Gauze: 8 Stretch: 50
Cotton cloth	Reused for two weeks	Cotton cloth should be washed daily with hot water and dried under sun	25 per meter
Cold cure foam sheet	Changed every 7 days	None	200 per sheet
Microcellular rubber sheet	Reused daily for one month or until it gets fully soiled by oil	None	498 per sheet
Sponge moulds	Changed every 7th day	None	Made from CCF sheets
Long stretch bandage	If exposed to oil, two weeks as rubber threads break or lose elasticity. Otherwise, three weeks	Washed every 10 days using cold water & bathing soap (should not be squeezed). Dried under shade by spreading on floor/paper	348
Short stretch	Patients use the same bandage for three months	Washing in cold water using bathing soap	Used when donated bandages are available
Bandage holding hooks	3-4 days for Indian made, European lasts for one week	None	Not available separately
Ribbed cotton stockinet (Dynamic Techno Medical)	One piece can be used for about a month	Cotton cloth should be washed daily with hot water and dried under sun	5cm x 10metres 286 7.5cm x 10metres 380 10cm x 10meters 440 15cm x 10meters 660

Inelastic bandages
Inelastic compression is undertaken after cotton cloth wrapping. A shift of oedema to the abdomen is frequently observed when using inelastic bandages (compared to long stretch bandages) in large size limbs, indicating a quicker lymph drainage effect. Inelastic products give superior results when used over firm, non-pitting, stable (little or no change in girth measurements following overnight elevation) lymphoedematous limbs. In addition, the fixation of the bandage is superior to long-stretch, thus providing constant compression for longer periods. It provides additional pressure and softens the limb. However, they are not routinely available on the Indian market, so bandages donated from European countries are used.

Compression stockings
Stockings are available in three sizes, large, medium and small. We recommend use after limbs attain their normal shape and size. As these ready made garments cause constriction at the upper end of the limb due to their elasticity, we ask the patients, to insert CCF pieces underneath where practical. If this is not possible, we recommend custom made stockings, although they are not routinely available.

Position of the patient for bandaging

Lying position: Used for foot and shin compression; the patient should sit on a cot with the limb supine *(Figure 3)*

Standing position: Here, the patient stands with both limbs apart, one limb on a 20cm high stool to create space for applying compression over the circumference of the limb

Straight leg raising position: The patient lies on cot with the limb at 90 degrees: used to apply compression at mid thigh particularly for protuberances sagging from thigh region *(Figure 4)*

'Bhekasana' position: Bheka=frog Asana=Position (position like a frog): The patient lies on cot in prone position with the affected leg bent backwards; compression begins from the foot *(Figure 5a)*. The position is used for swellings over maximum bulk and aids opening of the narrow crevasses created by the sagging oedema *(Figure 5b)*

Bandaging Techniques

Double layer compression: Here, the first layer of a short-stretch bandage is applied in a spiral and covered with a long-stretch bandage applied in a figure-of-eight *(Figure 6)*. This method is used to support the sagging skin and swelling when the oedematous out-growth becomes lax following lymph drainage. Short stretch is only possible when donated bandages are available.

Full compression: Compression is applied up to the groin in figure-of-eight. In unilateral limb swelling, the mid-thigh measurement of both limbs is compared. If the affected thigh measures 10% more than the normal thigh, the former is bandaged up to mid thigh *(Figure 7)*.

Half compression: If the oedema is limited up to knee level, bandages are applied up to knee joint in figure of eight *(Figure 8)*. One week after below knee compression, girth measurements are repeated and if thigh measurements have increased, the compression is extended up to mid thigh.

Half & half compression: Compression is given over the feet and leg (avoiding knee joint) and up to mid-thigh. Circumference at patellar region is measured periodically for oedema formation over the knee.

Forefoot compression: When foot oedema projects outwards towards the toes, the bandage is inserted into the crevasses underneath the protruded portion and above the toes and anchored over the malleoli, with the bandage running parallel to sides of feet *(Figure 9)*.

Figure 3: Lying position is used for applying compression to foot and shin

Figure 4 a and b

4a: *Straight leg raising position for bandaging*

4b: *Straight leg position used to expand the crevasses of oedematous overgrowth in thigh*

Figure 5 a and b

5a: *Bhekasana position*

5b: *bandaging of such swelling can only be achieved using the Bhekasana position*

Figure 6 a and b

6a: Short stretch bandage
6b: Long stretch bandage - double layer

Figure 7 a and b

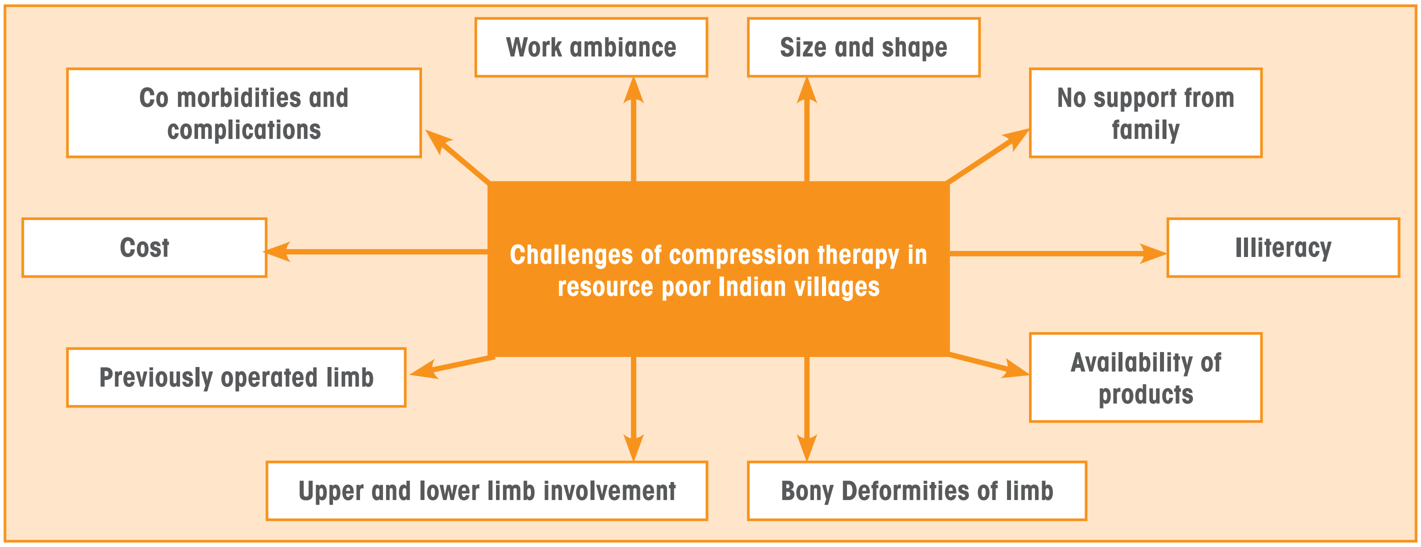
7a: In cases where the difference between girth on the normal limb and the affected limb is minimal, measurement is taken to confirm oedema before applying compression
7b: Full compression bandaging

Figure 8 a and b

8a: Compression *8b: Oedema to knee*

Figure 9: Teaching forefoot compression bandaging to patient's spouse; note that long stretch bandage runs parallel to the sides of feet to be anchored over malleoli

Figure 10: Challenges in delivering effective compression therapy in lymphoedema endemic villages in India



Challenges of compression therapy practice in the community

Lymphoedema is endemic in Indian villages where patients have to travel hours to reach a primary health centre. Providing compression is a skilled job and such expertise is not generally available, even in Indian cities. In addition there are other issues associated with the delivery of compression therapy in Indian rural areas *(Figure 10)*

Distortion of the limb: Irregular limb shape with lymphoedema at different anatomical regions, pose challenges to the therapist. Different size and shaped moulds are placed and inserted in crevasses to achieve the cylindrical uniformity of such limbs. Difficult limbs such as those in figures 11 a-d, are not treated at village units, instead referred to the Kasaragod centre of the IAD.

Co-morbidity and complications: Conditions such as large wounds, poor skin condition, oozing eczema, lymphorrhoea, maggots, repeated excoriation of tender skin, require special skills to manage. Large wounds *(Figure 12)* are treated with permanganate soaks and an Ayurvedic oil (Jatyadi Thaila) made from herbs[9] to debride the wound. Poliomyelitis, orthopaedic deformities, arthritis, obesity, other systemic diseases such as diabetes mellitus, can affect the delivery of uniform and optimal compression.

Bony deformities: Compression is difficult in limbs with deformities or restricted mobility due to osteoarthritis, rheumatoid arthritis and ossification *(Figure 12)*. Such patients usually have a compensatory gait pattern. Large sized limbs that is those which measure over 7 litres of limb volume, generally cause a gait problem requiring correction exercises. Such patients also develop clawed toes and multiple nodules over the toes, making toe compression and separation of folds at metatarsal region a challenge *(Figure 2c)*.

Involvement of more than one limb: 27% (545) of 2008 patients attending IAD treatment centres (IAD Kasaragod, Alleppey & Gulbarga) had both lower limbs affected by lymphoedema *(Figure 13)*. 2.7% of patients had genital involvement.

Previous surgery for lymphoedema: Lymphoedema is routinely treated using debulking surgery or nodovenous shunts in India. Patients with recurrence after debulking surgery generally present with multiple sequelae, such as non healing wounds and collagen deposition leading to difficulty in walking. Non debulked regions generally develop fresh oedema following surgery. 18 % (134) of patients attending the Kasaragod centre of IAD do so for treatment of surgical treatment sequelae. These recurrences are difficult manage and make achieving uniform compression more difficult. Pressure on scars may cause them to breakdown, causing ulceration, while oedema requires better compression *(Figure 14)*.

Figure 11 a-d: Severely distorted shapes pose great difficulty to achieve effective compression. Such limbs are treated in IAD's referral and training centre at Kasaragod

Figure 12: Wound and joint deformities, can prevent effective compression therapy

Figure 13: Lymphatic Filariasis affects more than one limb, genitalia and occasionally involves breasts

Figure 14: Debulking surgery of lymphoedema leads to uneven shape of limb with surgical scars and multiple folds. Compression is difficult in these limbs

Figure 15: Bandage durability is in those patients who work in contact with water, those who climb posts and trees, and manual laborers who work for daily wages. This often means they do not wear compression during the day

Work and compression: Labour can lead to soiling or wetting of bandages and limits their durability, so patients are reluctant to wear them at work. Moist bandages can facilitate bacterial entry, commonly intertrigo *(Figure 15)*. Therefore, only a small percentage of patients comply with the optimal usage recommendations.

Tropical climate: During summer compression can cause sweating and itching, leading to the development of lesions similar to miliaria rubra or folliculitis *(Figure 16)*, again acting as bacterial entry points.

Social issues: In all villages where the IAD has units, contrary to the general belief many patients live apart from their children for social reasons or because villagers migrate to cities for better economic opportunities. Therefore, family support is not forthcoming for bandaging and other procedures, particularly for women. Social stigma is associated with bandaging and in general patients don't wear compression outdoors.

Complications of improper compression

Toe compression: Excoriation, constriction, splaying of the 5th toe due to more pressure over 5th metatarsal region, and pain due to cracks observed on the plantar side of toes *(Figure 17)*

Short-stretch bandages: Frequently cause excoriation at its margins. When the oedema is reduced quickly, pain and numbness is observed. It is difficult to use over irregular shaped limbs as it slips into the crevasses resulting in rope-like constriction. When oedema reduces the bandage slips or rolls over, causing constriction.

Long-stretch bandages: Frequently cause constriction around knee and ankle joints due to slipping and loosening. Whenever large folds give deep crevasses, the bandage slips into the grooves and causes constriction, increasing the oedema below the folds *(Figure 18)*. Long-stretch bandages lose elasticity quickly, leading to splaying at the borders, risking constriction. The pressures produced are not adequate for largely distorted limbs, resulting in a 'ballooning effect' requiring more padding. Pressure urticaria is common when moulds and compression are removed. Unless patients are warned about this they might vigorously scratch causing minor bacterial entry points.

Sponge and MCR moulds: They occasionally cause excoriation, boils, irritant rashes and pruritis. *(Figure 19)*

Non availability of well fitting foot wear: Following compression, particularly when there is shape distortion of the foot, patients are unable to use well fitting footwear. The MCR footwear available in the market is expensive, doesn't fit well to all limbs, added to which, most patients are unable to afford it. *(Figure 20)*

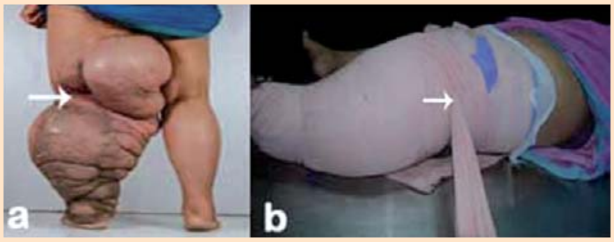
Figure 16: Folliculitis frequently occurs under the compression bandages in tropical climate

Figure 17 a and b

17a: Odematous toes quickly 'crack' due to pressure or rolling back of toe bandages

17b: Splaying of 5th toe. Little toe is not bandaged as intertrigo is common in the 4th web space

Figure 18 a and b



18a: Long stretch bandages are not optimal to bandage in large sized limbs with deep crevasses.

18b: They slip into crevasses and cause rope like constriction

Figure 19a-d

19a: Rolling back of long stretch bandages cause constriction effect at the upper part of bandage

19b: Arrow shows the excoriation caused by sponge moulds used to separate crevasse

19c: Friction induced blisters due to MRC mould placed directly over the skin

19d: Friction blisters following sponge mould

Figure 20 a and b

20a: Well fitting footwear is not available routinely in the market. Occasionally footwear used pushes the bandage backwards causing constriction.

20b: MCR footwear available in the market

Steps of compression

Step 1: After IMLD, the remaining oil stains are dried using cotton cloth followed by toe compression. The bandage, which is 6cm in width, is folded to make it 3cm and rolled over toes thrice. Later, the bandage is rolled in spiral manner around metatarsal for 3 times, then rolled over to great toe. The same procedure is repeated for remaining three medial toes.

Step 2: Cotton cloth wrapping is applied up to the level of oedema, covering the entire circumference of the limb.

Step 3: CCF and de-kinking materials are used to maintain uniformity in compression and a cylindrical limb shape.

Step 4: Compression is given by using long stretch bandages.

Teaching compression bandaging to patients and their families

Initially patients and their family members are taught about compression, particularly the figure of eight technique, using a dummy. Daily sessions take place from day seven of supervised care. All materials necessary for compression and the role of these materials are discussed. We discuss the role of foam, and why we cut its edges, cloth wrapping, MCR, chalky bags, and moulds. We outline how to manage constriction, rolling and numbering of bandages (to identify wear-time/durability). Videos of how to undertake compression are shown and patients and their home care givers participate in role play, using each other's normal limbs to practice on.

From day 9 of supervised care, compression is practiced on the patient's affected limb. In those patients who do not have the family support self compression is taught. Initially, they observe compression therapy given to the patient whom they accompanied. Later, a practical demonstration is given, including toe compression, cloth wrapping, CCF sheet preparation and placing, preparation of de-kinking materials, placing of sponge/MCR moulds, and figure of eight bandaging. Therapists conduct focus group discussions which the patients are asked to participate in. In the theory class, disinfection methods and durability of bandages and other accessory materials are discussed. The issues arising out of improper bandaging techniques are repeatedly emphasised *(Figure 9 and 21)*.

Cost of compression materials

Bandages and compression garments are very expensive for Indian patients. Inexpensive, durable bandages and garments need to be developed if this important therapy is to become routinely available in resource-poor areas. In the delivery of integrated treatment for lymphoedema 66% to 80.7% of total cost of medicines is for compression therapy.

Discussion

During the initial supervised phase adaptation of positions of yoga provided new insights for reshaping the large deformities. Bandaging the leg in a straight leg raising position or "Bhekasana" position helped to unfold the crevasses.

Paramedical workers, including a biomedical nurse and Ayurvedic paramedical workers provide compression to patients. During the last seven days of the supervised phase of treatment, the nurse trains the patient and home care giver on the use of compression therapy at home. In patients with small sized limbs (<7 litres of volume), whose family members cannot or will not support them, self-compression is encouraged. In patients with large sized, distorted limbs, the support of another person is required to achieve compression.

In India, physiotherapists are the compression professionals, but they are scarce, even in cities. Biomedical doctors do not go to rural areas, which has forced the Government to create special courses in rural medicine. However, as each primary health centre (PHC) in India has a minimum of one nurse, primarily because they are paid better, they, along with Ayurvedic paramedical workers, are trained in compression therapy. Unfortunately, areas remain where lymphoedema patients have no access to professional expertise; consequently, the IAD has implemented a compression program to endemic villages, which relies heavily on the training of family members to provide compression[9]. This training comprises sessions on figure of eight bandaging, how to prevent constriction caused by rolling back of bandages, and careful use of moulds for extra pressure as advocated by Foldi[8] and Moffat[7]. At each follow up, patients are asked to demonstrate self compression to identify and where necessary, rectify deficiencies in care giver's skill.

Short-stretch bandaging in combination with long stretch bandaging has a definite role in reshaping distortions, particularly when lymph is drained and the protuberances begin to hang. These are held firmly in place using short stretch, as long stretch bandages in such situations either cause excoriation or constrict their stalk. However, short stretch bandages alone do not stay on top of the distortions and slip into the crevasses causing constriction, and long stretch bandages induce a ballooning effect and occasionally worsen distortion. Therefore, to manage different presentations of lymphoedema in India we have used long stretch and short stretch in combination *(Figure 6)*. Whenever donated bandages are not available, sponge moulds are filled to stabilise distorted oedematous protuberances. Although economical, sponge and MCR moulds frequently cause excoriation and induce bacterial entry points. Continued compression over these superficial abrasions will run the risk of precipitating non healing wounds.

Wearing bandages has social stigma in India; in particular, parents of unmarried girls find it difficult to get alliances in the arranged marriage system prevalent in rural areas. Bandages are not acceptable in fishing or farming communities during work hours. In our tropical climate, sweat and heat generated by long hours of compression, often forces patients to remove the bandages.

Figure 21: Teaching self bandaging to patients and their family members

Figure 22: Response to integrated treatment of lymphoedema in patients who routinely used compression bandages for 10 hours in day time

Feedback from the community units and the Kasaragod centre of IAD (where patients from 18 Indian states attend) shows usage pattern of compression bandaging. Estimated hours of daytime wear ranges from o hours (manual workers) to 10 hours (housewife, blue collar worker), and at night, range was from 1 hour (pensioner), to 10 hours. Although most patients wear and practice bandaging techniques at less than the desired levels, the response to treatment is of the degree shown in *(Figure 22)*. The IAD is now collecting 'cohort data' from the rural community to determine the role of compression therapy in the integrated treatment of lymphoedema.

Repeated patient education sessions and telephone counselling are necessary to improve the self care compression delivery, otherwise it is not uncommon to see patients coming back with constriction and wearing the same bandages during cellulitis and worsening lymphoedema. It is clear from our experience that the products available on the Indian market do not meet all the needs of lymphoedema patients, and they are expensive; 66% to 77% of the total cost of medicines in the supervised phase and 71%-81% of total costs in the self care phase. As there is scarcity of products for routine use, patients and care givers have to be content with the available quality and products. Unfortunately, they do not meet the needs of tropical climate, so innovations are needed, for example, washable bandages with inner absorbable padding.

Compression therapy products available on Indian market are too expensive for patients to buy. Long stretch bandages are sold on a par with the short stretch selling price in Europe and America. Patients continue to use long stretch bandages even after elasticity is lost. The IAD has developed a minimum standard guideline for the purchase of accessory materials for compression from the local Indian market, although short stretch bandages are not available routinely in small Indian towns such as Kasaragod.

Compression therapy has special challenges in tropical climates and resource-poor settings not fully met by using available products in the market.

References

1. WHO (1997) *The Global Programme to Eliminate Lymphatic Filariasis.* www.who.int/lymphatic_filariasis/disease/en/
2. World health Assembly (1997) *Elimination of lymphatic filariasis as a public health problem.* Resolution WHA 50.29 www.paho.org/English/AD/DPC/CD/psit-lf-wha50-29-eng.pdf
3. Morgan PA, Moffatt CJ, Doherty DC, *et al.* (2005) UK Lymphoedema Framework Project. *EWMA J.* Vol 5 N° 2
4. Handicap International Madagascar (2009) data unpublished
5. Stout NL, Brantus P, Moffatt CJ. (2012) Lymphoedema management: An international intersect between developed and developing countries. Similarities, differences and challenges. *Glob Public Health.* 7 (2): 107-23
6. Narahari SR, Ryan TJ, Bose KS, *et al.* (2011) Integrating modern dermatology and Ayurveda in the treatment of Vitiligo and lymphedema in India. *Int J Dermatol.* 50: 310–334
7. Moffatt C. (2007) *Compression therapy in practice.* Wounds UK, Trowbridge
8. Foldi M, Foldi E, Kubic S. (2007) *Textbook of Lymphology.* Elsevier, Munich
9. Narahari SR, Ryan TJ, Mahadevan PE, *et al.* (2007) Integrated management of filarial lymphoedema for rural communities. *Lymphology.* 40: 3-13

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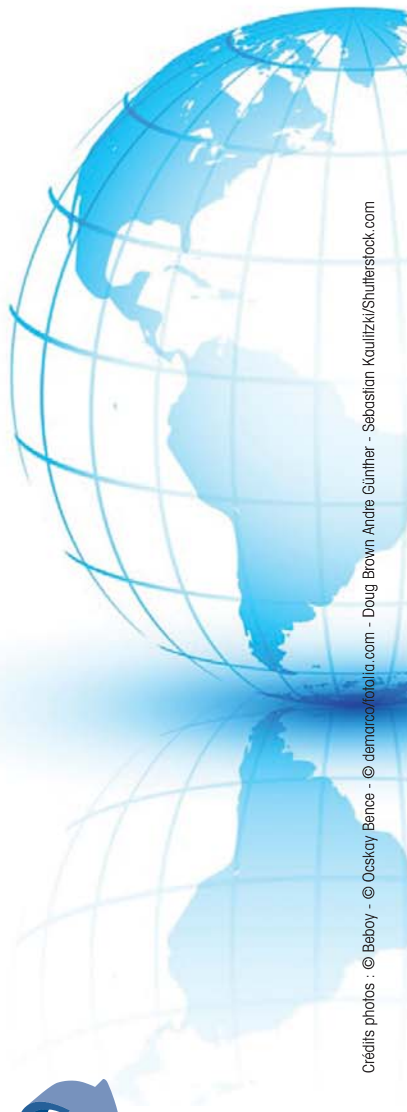
Please note that many of the images portrayed in this document are extreme cases of lymphoedema and lymphatic filiarisis primarily seen in patients from developing countries

The ILF Objective :

To improve the management of lymphoedema and related disorders worldwide

- To increase **awareness** by raising the profile of lymphoedema.
- To increase **knowledge** about lymphoedema by initiating and/or contributing to **Research Programmes.**
- To **disseminate** this knowledge by implementing an **international, not-for-profit, publications strategy.**
- To increase **understanding** of lymphoedema and its management by creating and/or contributing to the development **of Education Programmes.**
- To provide a cross cultural networking platform through an **Annual International Event** where all stakeholders will have the opportunity to contribute and influence the ILF agenda.
- To promote and document Best Practice with the development of an **International Minimum Dataset.**
- To facilitate and/or contribute to better **access to treatment** for patients worldwide.
- To promote and **support initiatives** whose goals are to improve the national/regional/local management of lymphoedema anywhere in the world.
- To help the Healthcare Industry understand the **real needs** of patients and practitioners, and develop and evaluate improved diagnostic tools and treatments.



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