

Obesity-related lymphoedema – underestimated and undertreated

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Keywords

Obesity, lymphoedema, multimodal obesity concept, bariatric surgery

Summary

The worldwide increase in the prevalence of obesity, which WHO has termed an epidemic, has brought about dramatic changes in lymphology. While 'classic secondary' lymphoedema after cancer surgery is decreasing thanks to improved surgical techniques, the number of patients with obesity-related lymphoedema is increasing exponentially. This shift in the lymphological patient population is still largely underestimated, and often denied. The topic is only marginally represented at scientific congresses and in the literature, if it is even mentioned at all. Feelings of helplessness dominate when dealing with these patients in clinical practice, despite there being good evidence of the pathophysiological association between obesity and lymphoedema. Obesity can cause lymphoedema and exacerbate pre-existing lymphoedema.

Treatment concepts focussing solely on the lymphoedema and ignoring obesity as a significant cause are therefore ineffective. Approaches to obesity that consist of dieting or commercial weight-loss programmes are equally counterproductive. Long-term studies have so far demonstrated only one thing – that such diets and weight-loss programmes fail.

At the Földi Clinic, obese patients with lymphoedema (and also with lipoedema) are treated with a multimodal obesity programme. The programme includes both general medical and psychological aspects, with additional bariatric and plastic surgery as required. Patient care is planned in the long term. Contrary to expectations, the treatment of patients with obesity-related lymphoedema is usually very rewarding, not only because they experience a basic improvement in their lymphoedema but also because many of them regain a normal, generally healthy lifestyle, thanks to the weight loss made possible by bariatric surgery.

Schlüsselwörter

Adipositas, Lymphödeme, multimodales Adipositas-konzept, bariatrische Chirurgie

Zusammenfassung

Der weltweite Anstieg der Adipositasprävalenz – die WHO spricht bereits von einer Adipositas-epidemie – hat auch eine dramatische Veränderung innerhalb der Lymphologie zur Folge. Während „klassisch sekundäre“ Lymphödeme nach onkologischen Operationen aufgrund verbesserter OP-Techniken abnehmen, steigt die Zahl von Patienten mit Lymphödem, die Adipositas-assoziiert, sind exponentiell an. Dieser Wandel im lymphologischen Patientengut wird aktuell noch weitgehend

unterschätzt – häufig auch negiert. So ist dieses Thema sowohl auf wissenschaftlichen Kongressen als auch in der Fachliteratur, wenn überhaupt nur marginal repräsentiert. Im klinischen Umgang dominiert vor allem Hilflosigkeit gegenüber diesen Patienten. Dabei ist der pathophysiologische Zusammenhang zwischen Adipositas und Lymphödem inzwischen gut belegt. Adipositas kann Lymphödeme verursachen bzw. bestehende Lymphödeme verschlechtern. Therapiekonzepte, die isoliert das Lymphödem fokussieren, die Adipositas aber als wesentliche Ursache ignorieren, sind daher nicht zielführend. Ebenso kontraproduktiv ist ein therapeutischer Ansatz, der Adipositas mittels Diäten bzw. durch kommerzielle Gewichtsreduktionsprogramme behandelt. Diäten und Gewichtsreduktionsprogramme haben im Langzeitverlauf bisher nur eines bewiesen – dass sie scheitern. In der Földiklinik werden adipöse Patienten mit Lymphödem (auch mit Lipödem) im Rahmen eines multimodalen Adipositasprogramms behandelt. In diesem Programm werden u. a. internistische, psychologische, ggf. auch adipositaschirurgische und plastisch-chirurgische Therapieoptionen angewandt; die Betreuung der Patienten ist langfristig angelegt. Entgegen Vermutungen ist die Therapie von Patienten mit Adipositas-assoziierten Lymphödem meist sehr dankbar, dankbar weil Patienten nicht nur eine essenzielle Verbesserung ihres Lymphödems erfahren, dankbar auch, weil viele Patienten durch die im Rahmen eines adipositaschirurgischen Eingriffes erfolgte Gewichtsreduktion wieder in ein normales, weitgehend gesundes Leben zurückkehren.

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Adipositas-assoziierte Lymphödeme – unterschätzt und unterbehandelt

Phlebologie 2018; 47: 75–83

<https://doi.org/10.12687/phleb2410-2-2018>

Submitted: 08. January 2018

Accepted: 28. January 2018

Introduction

Obesity goes far beyond ‘eating too much and taking too little exercise’.

The causes of obesity are multiple and very complex. There is scientific evidence for genetic and, in particular, epigenetic influences (68–71). Biological factors such as stress or addictive behaviour may also affect weight (72, 73). Mental health issues such as depression and eating disorders contribute heavily to obesity (74). And finally, sociocultural changes play an important part in the development of obesity. Factors include changes in eating habits, excessive sugar consumption (especially in soft drinks and industrially manufactured foods), and a more sedentary lifestyle, as well as a perception of beauty firmly anchored in an underweight ideal body shape and closely linked to a diet culture that often starts in the teenage years (75, 76).

The epidemic spread of obesity (1) is not only a medical problem: the increasing prevalence of obesity also poses economic, political, and psychosocial problems. In Germany, almost 25% of people are obese (BMI > 30 kg/m²) (2), while the corresponding figure for the USA was already 40% in 2017 (3).

Obesity is associated with numerous sequelae. Cardiovascular, endocrine, orthopaedic, and psychiatric conditions are closely related to obesity (4). Obesity-related disorders in the field of lymphology are relatively unknown. But the present obesity epidemic is having a huge – and ap-

parently underestimated – effect on the two most common clinical lymphology conditions requiring treatment: lymphoedema and lipoedema.

Lymphoedema and obesity

Lymphoedema is usually classified into primary and secondary disease. Primary lymphoedema arises from a developmental disorder (dysplasia or aplasia) of the lymphatic vessels or lymph nodes in certain regions of the body. The underlying cause of secondary lymphoedema is a disorder of lymphatic drainage occurring later in life, usually due to trauma or cancer. In clinical practice, secondary lymphoedema is mostly a result of cancer surgery with dissection of the lymph nodes and associated lymphatic vessels. But radiotherapy and chemotherapy may also be the cause of lymphoedema (77).

Apart from the classic division of lymphoedema into primary and secondary, obesity-related lymphoedema plays a very minor role in the literature. Although there have been isolated publications on lymphoedema in morbid obesity since 1998, they have focussed only on ‘localised lymphoedema’, which at the time was also incorrectly called ‘pseudosarcoma’ (5, 6, 7). Given the enormous increase in lymphoedema related to obesity in recent years, this narrow perspective is astonishing.

The Földi Clinic in Hinterzarten near Freiburg is the largest specialist clinic dedi-

cated to lymphology in the world. Patients whose lymphoedema or lipoedema is related to obesity now comprise the largest and most rapidly growing group of patients in both statutory health insurance (SHI) outpatients and hospital inpatients.

► Figure 1 shows the increasing prevalence of obesity in the Földi Clinic between 2005 and 2015.

► Figure 1 shows that there was only a slight increase in the number of patients with a BMI between 30 and 40 kg/m² in these 10 years but an exponential increase in the patients with a BMI greater than 40 kg/m². The Földi Clinic treats about 6000 patients a year (4000 ambulatory care, 2000 inpatients). In 2015, 66% of our patients were obese (BMI > 30 kg/m²); 38% were morbidly obese (BMI > 40 kg/m²). This clearly shows the high absolute number of severely obese patients treated each year in the specialist lymphology clinic.

In our experience, the risk of developing lymphoedema rises sharply with a BMI of 40 kg/m² or more. It seems, however, that there must also be a ‘primary disposition’ towards impaired lymphatic drainage; after all, not all morbidly obese people suffer from lymphoedema. But patients with a BMI below 40 kg/m² may also develop lymphoedema if they have this primary disposition together with other conditions that exacerbate lymphoedema, such as diabetes, heart failure, chronic venous insufficiency (CVI) or immobility.

Typical areas of localised lymphoedema are the lower limbs, the genitals, and the abdominal wall. ► Figure 2 shows a female patient with a BMI of 48 kg/m² and pronounced distal lymphoedema of the legs. ► Figure 3 shows a male patient with a BMI of 66 kg/m² and lymphoedema of both legs (more marked distally), the genital region, and the abdominal wall.

In super morbidly obese patients (► Figure 4 BMI > 50 kg/m² and ► Figure 5 BMI > 60 kg/m²) there may also be severe local lymphoedema, which was formerly incorrectly called ‘pseudosarcoma’, as mentioned above.

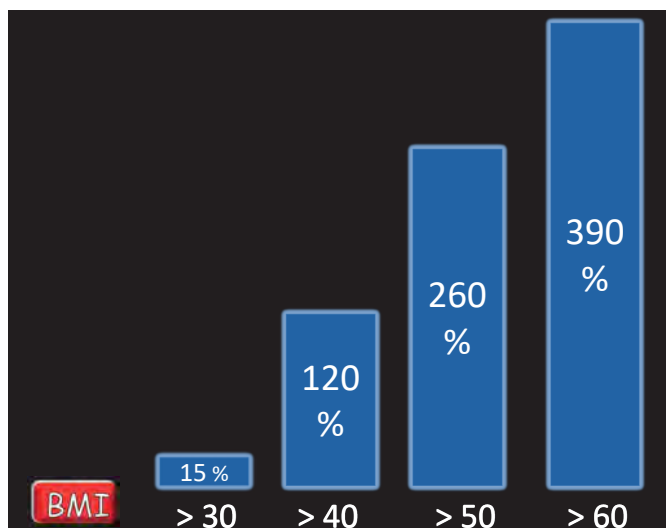


Fig. 1
Increasing prevalence of obesity in the Földi Clinic between 2005 and 2015

Pathophysiology

How can we explain the relationship between obesity and lymphoedema? Or to put it another way: why do super morbidly obese people have such a tendency to lymphoedema? From the clinical perspective, it seems obvious that there is a link between these two phenomena that so frequently occur together.

The close relationship can also be seen in the histology from Prof. Zöltzer (► Figure 6). This image clearly shows that the lymphatic vessels (pre-collector shown here) and the fat cells lie in very close proximity.

While an increase in visceral or abdominal fatty tissue is well known to correlate strongly with insulin resistance and cardiovascular diseases (9), the increase of subcutaneous fatty tissue does not have the same negative effects on our metabolism. It does, however, have a very considerable effect on the functions of the lymphatic system.

We now know that lymphatic vessels are surrounded by subcutaneous fatty tissue (10). This perilymphatic fatty tissue is – in terms of an energy source – metabolically essential not only for lymphatic drainage but also for the immunological function of the lymphatic system (11). An increase in fatty tissue due to obesity leads to an increased secretion of adipose tissue hormones (adipokines) with localised chronic inflammation of the perilymphatic fatty tissue. Adipokines such as leptin, TNF-alpha and HIF-1-alpha have a proinflammatory effect with resultant damage to the lymphatic vessels, while adiponectin is of a protective nature (78).

Rutkowksi has shown that local inflammation of the perilymphatic fatty tissue may lead to leakage of lymph from the lymphatic vessels (12).

Other studies have confirmed that obesity not only impairs lymphatic drainage but also reduces the uptake of lymph into the lymph nodes (13, 14). Weitmann et al. provided evidence that obesity was responsible for changes in lymph node architecture: the lymph nodes showed an altered (reduced) internal structure. At the same time, the size and number of lymph nodes were also reduced (15).



Fig. 2 Female patient with a BMI of 48 kg/m² and pronounced distal lymphoedema of the legs

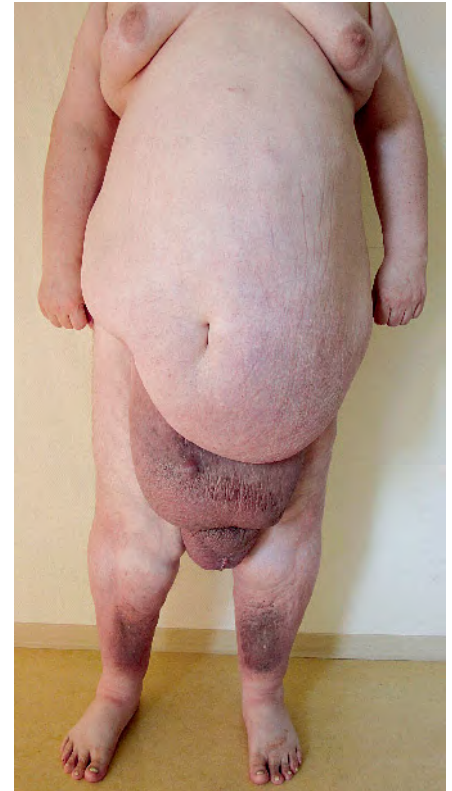


Fig. 3 Patient with a BMI of 66 kg/m² and lymphoedema of both legs (more pronounced distally), the genital region, and the abdominal wall

Blum et al. demonstrated not only a reduced frequency of muscle contraction in the collecting lymphatic vessels (lymphangiomotor function) but also a diminished response to mechanical stimulation of the vessels in obese mice. Lymphatic drainage was thus considerably impaired in these animals (16).

From investigations in the 1980s made by Földi (17) and more recently by Zampell (18), we also know that a bidirectional relationship exists between obesity and lymphatic vessel damage. These two researchers ablated lymphatic vessels in rabbits and mice. The result of this procedure was not only lymphoedema but also increased subcutaneous fatty tissue in the surrounding area. ► Figure 7 clearly shows these changes with lymphoedema of the right arm.

The lymphostasis-inducing increase in fatty tissue results in an increased secretion of adipokines, which in turn cause further damage to the lymphatic vessels. A vicious circle ensues.

And finally, mechanical factors can also impair lymphatic drainage. The mobility of morbidly obese patients is often reduced.



Fig. 4 Super morbidly obese patient (BMI > 50 kg/m²)



Fig. 5 Super morbidly obese patient (BMI > 60 kg/m²)

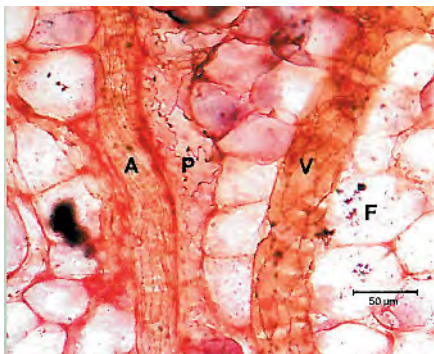


Fig. 6 Lymphatic vessels (pre-collector vessel shown here) and fat cells lie in close proximity [Prof. Hellmuth Zöltzer in *Lymph Forsch* 2008 (A = artery, P = pre-collector vessel, V = vein, F = fat cells)] (8).



Fig. 7 Lymphoedema of the right arm (reproduced with the kind permission of Hakan Brorson)

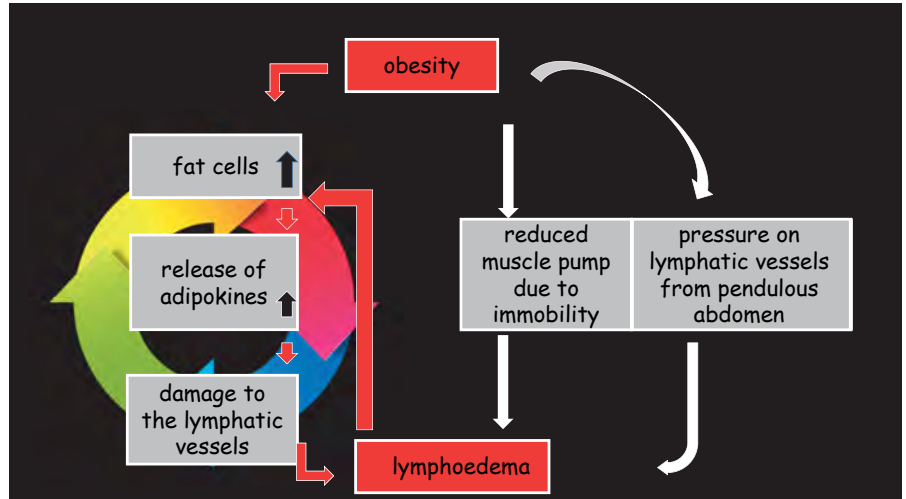


Fig. 8 Diagram of the complex aetiology of obesity-related lymphoedema

Effects of the muscle pump induced by movement are, however, essential for lymphatic drainage. Super morbidly obese people often have a very pendulous abdomen, which compromises lymphatic vessels and veins in the groin (19) and further impairs lymphatic drainage.

► Figure 8 illustrates these relationships; the vicious circle described above is represented by the coloured circle.

Treatment

In treating obesity-related lymphoedema, we have to focus on two diseases: on the lymphoedema itself and on obesity as the cause of the lymphoedema (or the cause of exacerbation of the lymphoedema).

Disorder: lymphoedema

The gold standard of lymphoedema treatment is complex decongestive therapy (CDT), which consists of the following components:

- Skin care and, if necessary, treatment of any infection
- Manual lymphatic drainage (MLD), with additional manual techniques if necessary
- Compression therapy with special multi-layered compression bandages and/or lymph compression hosiery (usually flat-knit material)

- Sport/exercise therapy to promote decongestion
- Explanation and training in individual self-therapy (20).

This largely undisputed concept of treating lymphoedema has been used successfully for many years.

Disorder: obesity

There is far less consensus on the question of how to manage the second disorder – obesity – in the context of lymphoedema.

There are two distinct approaches:

1. Denying or ignoring obesity

In clinical practice, this strategy is very often adopted through the diagnosis of ‘lipolymphoedema’. Every day we see obese patients with a BMI over 40, 50 or even 60 kg/m² who have been referred to us as outpatients or inpatients with this diagnosis. Behind the concept of ‘lipolymphoedema’ lies the idea that lipoedema leads to weight gain through an almost uncontrollable increase in fatty tissue. (Lipoedema is the subject of a separate article in this journal.) According to many lymphologists, this increase in fatty tissue mechanically compromises the lymphatic vessels with resultant lymphoedema (21, 22).

It has to be emphasised that there is no scientific evidence for this widely held be-

lief. Even so, the notion is generally accepted in patient circles as well as by many healthcare professionals. In our SHI lymphology outpatient clinic (where we see about 4000 patients each year), 'lipolymphoedema' is now by far the most common misdiagnosis in referrals.

At this juncture, it should be mentioned that the diagnosis 'lipolymphoedema' is a poor word construct anyway. 'Lipolymphoedema' suggests that lipoedema leads to lymphoedema; it suggests that lipoedema is the cause of the lymphoedema. Some classifications even describe 'lipolymphoedema' as stage IV lipoedema (23, 24).

There is, however, no evidence at all for this popular conception. In fact, our experience in routine clinical practice is quite different: a patient with lipoedema, who is already obese with a BMI of, say, 35 kg/m², gains a further 20 to 40 kg in the course of just a few years. As a result, lymphoedema may occur in addition to the lipoedema. We are convinced, however, that the lymphoedema is not lipoedema-induced but much rather obesity-induced. The underlying pathophysiology is described above. The patient therefore suffers from three different diseases: morbid obesity, lipoedema, and obesity-related lymphoedema. We frequently see these conditions occurring together in our patients. In my opinion, the term 'lipolymphoedema' should therefore be deleted from lymphological terminology. We have not used this term in the Földi Clinic for many years now. ▶ Figure 9 shows a female patient with morbid obesity, obesity-related lymphoedema, and lipoedema. This patient also has CVI, diabetes and hypertension.

2. Treating obesity with 'diet and exercise'

The usual advice given to obese patients is 'eat less (or follow a diet) and take more exercise'.

Specialists in nutritional medicine and dieticians formulate this recommendation more precisely and consequently in a more complicated manner. The guidelines of the German Society of Obesity (DAG) state 'Treatment is aimed at a long-term lifestyle change with lower energy density foods and an increase in physical activity' (25).

The long-term benefit of this recommendation as experienced by obese patients is usually non-existent. The DAG guidelines also recommend various weight-loss programmes, explicitly mentioning commercial programmes such as 'Mobilis', 'weight watchers', 'Abnehmen mit Genuss' etc. The key feature of all the programmes mentioned is invariably some form of diet, sometimes euphemistically referred to as a 'nutritional change'.

Looking back at the history of diets in the past decades, it becomes apparent that the criterion as to when a diet can be evaluated as successful has been continuously watered down over the years. Once it had been established that only a few patients achieved a weight loss of 20%, the figure was lowered – first to 10% and then to 5% (26, 27, 28). The extremely modest 'therapeutic success' of these commercial weight-loss programmes can also be seen in the current Association of the Scientific Medical Societies in Germany (AWMF) guidelines on the prevention and treatment of obesity (29).

Even though nutritional scientists, in league with the diet industry, have continuously lowered the bar, patients do not view the success of a diet in the same light. In one study with 130 subjects, not a single participant was satisfied with a weight loss of only 5% (30). This discrepancy between marketed success and perceived success has been confirmed in further studies (31).

Another reason why diets or weight-loss programmes should be viewed with caution is that many studies have reported failure in the long term.

Taking a closer look at the scientific evidence on the programmes for treating obesity mentioned in the AWMF guidelines, we can see that satisfactory weight loss is recorded only for the first year. Not infrequently, these twelve-month studies are marketed as long-term success or sustained weight loss (32). In actual fact, the question remains as to why hardly any long-term data are available, despite the many years that diet programmes such as weight watchers have been in existence. The few existing long-term studies on diets present a shocking picture (33–40).

Depending on the study, between 80% and 99% of participants in diet pro-



Fig. 9 Female patient with morbid obesity, obesity-related lymphoedema, and lipoedema

grammes regain the weight they had lost and many of them weigh even more than when they first started (41). Meta-analyses show that people of normal weight who 'diet' have a higher risk of obesity than those in a control population who do not (42). In order to take possible genetic factors into account, a Swedish study followed 4000 twins over nine years. This study also showed that, far from reducing the risk of obesity, 'dieting' tended to increase the likelihood (43).

Even though voicing these facts regularly provokes an outcry from dieticians and specialists in nutritional medicine, they remain the facts – facts for which there is ample evidence.

The reasons why diets and nutritional medicine fail are complex, but have now become clear. A comprehensive presentation of the many physiological processes that lead to regaining weight after successful weight loss is beyond the scope of the present article. There is, however, good evidence that endocrinological, psychological, metabolic, and neurophysiological changes that occur during the loss of weight contribute significantly to regaining it (45–48).

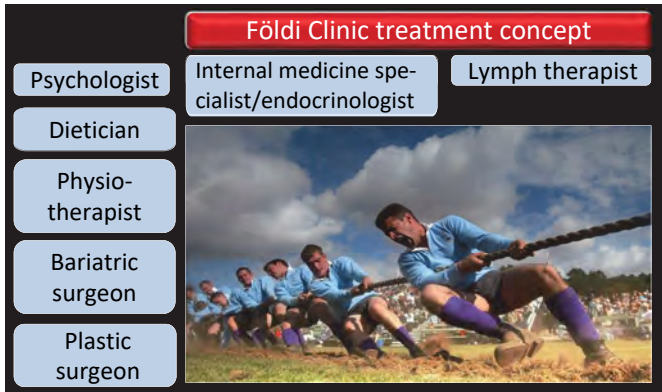


Fig. 10 Many different health-care workers pull together in our obesity programme

1. Focus on the obesity instead of ignoring it!

We have recognised that obesity is a significant contributory factor in the development or exacerbation of lymphoedema and lipoedema. Focussing on treatment of the lymphoedema (or lipoedema) alone is not effective and merely provides short-term improvement of the lymphological disease.

2. Recognise obesity as a disease!

Obesity is a disease and is recognised as such by WHO and the American Medical Association (50, 51). This essential attitude towards patients is reflected in the perception of obesity in our general medical and psychological activities at the Földi Clinic. We do not regard obesity as culpable behaviour and the result of a weak will or lack of self-discipline, but as a disease with multiple and extremely complex causes, which is not to say that obese people are helplessly at the mercy of their disease. It is all about a change of attitude, moving away from concepts such as guilt and self-indulgence towards respect and understanding for the situation of others. The distinctive attitude of our staff – encompassing respect and empathy – is also gratefully appreciated by our patients.

3. Changes in therapeutic goals

The automatic focus on weight loss for overweight patients suggests that overweight and obesity are inevitably associated with increased mortality. In actual fact, the data are not consistent about the level of BMI associated with an increased mortality risk. While some studies consider that a BMI above 25 kg/m² carries an increased risk, other studies have found that the risk is significantly increased at 30 kg/m² or 35 kg/m² (52–54).

Studies on the question of the variables that really predict early mortality are far more convincing and consistent. Obesity is not listed in the top five: ‘poor fitness’, ‘smoking’, ‘high blood pressure’, ‘low income’ and ‘loneliness’ are each better predictors of increased risk than overweight or obesity (55–57).

In addition, we have been living in an environment that contributes considerably to overweight (‘obesogenic environment’) for some time now (49).

Given the available historic and more recent studies, it is very surprising that the overwhelming majority of doctors still urge their obese patients to lose weight. It is obvious that patients are being encouraged along a path that in the long run will only lead to further weight gain.

Obesity concept in the Földi Clinic

The dataset described above agrees with our daily clinical experience of obese patients. All of them manage to lose weight but only a few manage to sustain the weight loss! We have therefore modified our own approach to the treatment of obese patients with lymphoedema or lipoedema. Our therapeutic approach is based on five pillars, which are outlined briefly below.



Fig. 11 Patient with obesity-related phlebo-lymphoedema – before taking part in the Földi Clinic obesity programme



Fig. 12 Patient with obesity-related phlebo-lymphoedema – about 2 years after participating in the Földi Clinic obesity programme

For this reason, we have changed the therapeutic goals for our overweight and obese patients at the Földi Clinic. Instead of focussing on weight loss, we focus on a stable weight. Instead of focussing on weight loss, we focus on daily exercise, healthy eating, fitness, and quality of life.

Instead of ‘diet and exercise’, our credo is ‘stabilise and exercise’!

4. Weight-loss programmes are not the solution to obesity – they are part of the problem

From what has been said earlier, it follows that we inform our patients about the real, and futile, chances of success with dieting. Many of our super morbidly obese patients have a diet career spanning decades with resultant weight cycling. Given the data already mentioned, which are reflected in our patients’ biographies, we strongly advise our patients against diets. We consider diets and weight-loss programmes to be business models that have economic benefits solely for the diet industry and the doctors allied with them (79, 80).

Instead of emphasising weight loss and diets, we merely advise patients about healthy eating. A key element is to explain the well-substantiated association between sugar (in all its forms and guises) and weight gain (58–62). Another major focus is to encourage patients to exercise. In addition to the goals of stabilised weight and improved fitness, exercise therapy is also part of complex decongestive therapy in the treatment of lymphoedema.

5. Metabolic surgery in super morbidly obese patients

If a patient has a BMI of 40 kg/m² (or BMI 35 kg/m² if there are severe concomitant medical conditions), we consider whether they will benefit from surgical intervention. Since 2009, we have been offering a multimodal obesity programme at the Földi Clinic, with bariatric surgery as a key component. The programme includes comprehensive general (internal) medical, endocrinological, surgical, and psychological assessment. It also contains modules that emphasise the importance of daily exercise and provide nutritional counselling to ex-



Fig. 13 Patient with obesity-related oedema of the legs and pronounced localised lymphoedema of the left thigh before participating in the Földi Clinic obesity programme

plain and support the postoperative reintroduction of solid food and necessary dietary supplements. Each week there is a meeting of the ‘obesity board’, which consists of a specialist in internal medicine (with additional ‘SCOPE’ qualifications in obesity), an endocrinologist specialising in diabetes, and a qualified psychologist (psychotherapist) with a particular interest in this group of patients. The board reviews whether patients are eligible for surgery before we refer them to the bariatric surgeons for assessment. Plastic surgery may also be performed to resect excessive skin flaps one or two years after the bariatric surgery. The programme is designed long-term, so we see patients about every nine months in our SHI lymphology outpatient clinic, or more frequently if necessary.

► Figure 10 shows how many different healthcare workers are pulling together in our obesity programme

The number of available studies on bariatric surgery is impressive. Many contain long-term results confirming therapeutic success after 5 years, 7 years, 15 years, and even 20 years (63–68). We have been seeing the positive effects that sustained weight



Fig. 14 Patient with obesity-related oedema of the legs and pronounced localised lymphoedema of the left thigh approximately two years after participation in the Földi Clinic obesity programme

loss following bariatric surgery has on lymphoedema, and also on lipoedema, since 2009. Together with the University Hospital in Freiburg, we are conducting an ongoing study that should provide scientific data on this approach.

► Figures 11 and 12 show a male patient with obesity-related phlebo-lymphoedema before and about two years after participating in the obesity programme at the Földi Clinic. On his first admission to the Földi Clinic, the patient’s BMI was 56 kg/m². After appropriate preparation for bariatric surgery, a gastric-bypass operation was performed four months after his discharge from the clinic. Eighteen months later, the plastic surgeons tightened the skin on both thighs. The patient has requested abdominoplasty; his BMI is currently 29 kg/m². Improvement in the lymphoedema (phlebo-lymphoedema) of the legs is clearly visible.

► Figures 13 and 14 show a female patient with obesity-related oedema of the legs with marked localised lymphoedema of the left thigh before and about two years after participating in the obesity programme at the Földi Clinic. Her BMI when she was first admitted was 52 kg/m². After a sleeve gastrectomy and stabilising her weight at a BMI of 31 kg/m², skin flaps on both thighs were resected. The patient also had an inverted T abdominoplasty. Once again, there is a huge improvement in the lymphology findings.

Summary

Obesity-related lymphoedema presents an increasing challenge in the field of lymphology. Sustained successful treatment is only possible if obesity is recognised as a significant cause of lymphoedema and also treated. Patients should be strongly advised against commercial diets and weight-loss programmes because of their proven lack of success. Metabolic surgery is an important therapeutic option in morbidly obese patients. It should, however, be incorporated into a multimodal long-term treatment concept.

Acknowledgement

I would like to thank Prof. E. Földi for her personal and professional support.

Conflict of interest

The author declares that he has no conflict of interest.

Ethical guidelines

No studies on humans or other animals were carried out in the preparation of this manuscript.

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