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EXTRACORPOREAL SHOCK WAVE THERAPY AS A POTENTIAL THERAPEUTIC TOOL FOR BREAST CANCER RELATED LYMPHEDEMA: A NARRATIVE REVIEW OF *IN VITRO*, ANIMAL AND CLINICAL STUDIES

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A – study design, **B** – data collection, **C** – statistical analysis, **D** – interpretation of data, **E** – manuscript preparation, **F** – literature review, **G** – sourcing of funding

ABSTRACT

Background: The treatment of breast cancer related lymphedema (BCRL) focuses on the alleviation symptoms. One of the innovative, non-invasive therapies used for this condition is extracorporeal shock wave therapy (ESWT).

Aim of the study: To review the available literature and evaluate the effectiveness of ESWT in the treatment of secondary lymphedema (*in vitro* works, animal experiments) and lymphedema associated with the treatment of breast cancer.

Material and methods: The scientific literature review was conducted from October to December 2020. The review was carried out by searching scientifically recognized medical databases, including PubMed, MEDLINE and PEDro. Date restrictions were not applied. As there are only a few clinical studies assessing the effectiveness of ESWT on the reduction of lymphedema, case reports, animal experiments and *in vitro* works were included in the review. Articles written in a language other than English were excluded.

Results: In total, the analysis included twelve studies, including seven clinical trials, one case report, three animal experiments and one *in vitro* test.

Conclusions: Based on the results of the analyzed articles, ESWT can be an effective therapeutic tool for lymphedema occurring after breast cancer treatment. Unfortunately, the level of evidence is relatively weak since the number of publications on this subject is still quite low. The accumulated results indicate the need for further clinical trials.

KEYWORDS: lymphedema after breast cancer, ESWT, shockwave, effectiveness

BACKGROUND

Breast cancer is one of the three most frequently diagnosed cancers among women and is the most common cause of death in this population [1,2]. It is estimated that around 10% of women worldwide currently suffer from breast cancer [3]. There are many treatment methods available for this condition, with the most common being surgical procedures (mastectomy, lumpectomy), radiotherapy, and chemotherapy [4].

Breast cancer treatment is associated with the occurrence of various complications. One of these is upper limb lymphedema, which is recognized as the most bothersome and problematic symptom for female patients [5-7]. Lymphedema is characterized by the accumulation of fluid in the tissues. The primary cause of edema is a dysfunction of the lymphatic system induced by the removal or damage of axillary lymph nodes, or lymphatic vessel obstruction, during cancer treatment [8,9].

The treatment for breast cancer related lymphedema (BCRL) primarily involves symptomatic management. These treatments include both invasive and non-invasive methods. Among the methods that do not require surgical intervention are comprehensive anti-edema therapy (manual lymphatic drainage, pneumatic compression, bandaging, exercises and compression garments), laser therapy, and kinesiotaping [6,9,10-13]. Available reports also indicate that the shock wave therapy may be effective for the treatment of lymphedema.

Extracorporeal shock wave therapy (ESWT) is widely used in clinical practice. Due to the way that the energy is supplied to the tissues, the beam shape and its physical properties, shock wave therapy can be divided into two basic types: focused extracorporeal shock wave therapy (FSWT) and radial extracorporeal shock wave therapy (RSWT) [14]. FWST is referred to as "focused" because the generated waves penetrate deeply into tissues to focus on a small and specific area with a radius of approximately 5 mm. There are three methods for generating the focus wave: electrohydraulic, electromagnetic and piezoelectric. Depending on the type of generator used, the supplied energy can reach a value of 1.5 mJ/mm^2. Focused waves may penetrate tissues to a depth of a few to even 8 cm. Penetration depth depends on the choice of the wave generating method and on the amount of energy provided to tissues. Unlike FSWT, RSWT generates a diffuse wave that reaches its maximal pressure at the source and spreads radially through tissues. Therefore, it has a more superficial effect. The energy of the radial extracorporeal shock wave is much lower than that of FSWT and reaches a maximum value of 0.15 mJ/mm^2 [15-17].

This review is a compilation of the scientific evidence that supports the effective use of ESWT in the reduction of lymphedema, including BCRL.

AIM OF THE STUDY

The aim of this work is to review the pre-clinical (*in vitro* and animal studies) and clinical literature on the use of ESWT in the treatment of secondary lymphedema, including that observed in breast cancer patients.

MATERIAL AND METHODS

A systematic literature review was carried out in the period from October to December 2020. Its aim was to evaluate the effectiveness of ESWT for the treatment of lymphedema in female patients after breast cancer. The systematic review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA).

The review was carried out by searching the scientifically recognized medical databases PubMed, MEDLINE and PEDro. After an initial search of the literature, the following search terms were used: (effectiveness) and (lymphedema or lymphedema after breast cancer) and (ESWT or shock wave). During the literature search no date restrictions were applied. Due to the low number of clinical trials assessing the effectiveness of ESWT on the reduction of lymphedema, case reports, animal experiments and *in vitro* works were also included in the review. Articles written in a language other than English were excluded.

The review and evaluation of the identified articles was conducted by two researchers. The analysis focused on the characteristics of the materials and methods, results and conclusions. Preliminary parameters to be assessed were the range of motion, volume and dexterity of the upper limbs, the thickness of skin folds, and questionnaires.

RESULTS

Twelve studies were included in the analysis. A breakdown of the different types of studies included is presented in Figure 1.

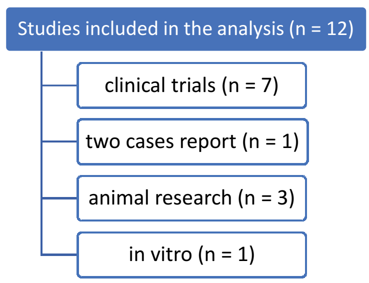

Figure. 1. Types of studies included in the analysis

The use of ESWT in lymphedema treatment is a relatively recent development. In recent years, growing interest in this method may have arisen from the fact that ESWT, at the cellular level, shows a positive effect on the lymphatic system and processes related to its reconstruction/regeneration. Tests carried out on animals have confirmed these effects [18]. While studies in this area are limited, researchers have been willing to attempt to treat BCRL using shock wave-based therapies. The small number of studies provides a basis to analyze, among other things, the treatment parameters used and the therapeutic effects obtained by this method. The characteristics of the included articles are presented in Tables 1 and 2.

Table 1. Characteristics of the included *in vivo* and *in vitro* pre-clinical studies

Author	Publication year	Type of study	Groups	Number of patients (n)	Energy SW [mJ/mm²]	Number of ESWT pulses	Frequency [Hz]	Period of treatment (weeks)	Number of treatments
Rohringer et al.	2014	*in vitro*	—	—	0.03–0.19	200	5	—	—
Kubo et al.	2010	*in vivo* (rabbit ear model)	treatment	7	0.09	200	—	4	12
Serizawa et al.	2011	*in vivo* (rat tail model)	treatment	45	0.25	500	—	1.5	4
			control	45					
Kim In Gul et al.	2013	*in vivo* (mouse lower limb model)	treatment (n=4)	5 (20)	0.05	500	3	4	10
			control	5					

Table 2. Characteristics of the included clinical trials

Author	Publication year	Type of study	Groups	Number of patients (n)	Energy SW [mJ/mm²]	Number of ESWT pulses	Frequency [Hz]	Period of treatment (weeks)	Number of treatments	PEDro scale
Kim So-Yeon et al.	2015	two cases report	—	—	0.04–0.069	2000	5	2	16	—
Bae et al.	2013	pilot study	treatment (traditional physiotherapy program + ESWT)	4	0.056–0.068	2000	—	2	4	—
			treatment (ESWT)	3						
Hesham et al.	2015	randomized, controlled clinical study	treatment	20	*E equal to pressure 2 bar	2500	4	8	16	5
			control	20						
El-Shazly et al.	2016	randomized, controlled clinical study	treatment	30	0.004–0.069	2000	5	6	12	4
			control	30						
Cebicci et al.	2016	pilot study	treatment	11	*E equal to pressure 2 bar	2500	4	4	12	—
Abdelhalim et al.	2018	randomized, controlled clinical study	treatment (ESWT)	21	*E equal to pressure 2 bar (90 mJ)	2500	4	4	12	7
			treatment (IPCT)	22						
Lee Kyeong Woo et al.	2020	randomized, controlled clinical study	treatment	15	0.056–0.068	2500	—	3	6	4
			control	15						
Josset et al.	2020	pilot study	treatment	10	0.10	2500	4	4	8	—

In vitro research

Jones et al. [19] investigated the effect of ESWT on lymphatic endothelial cells (LECs) and *in vitro* lymphangiogenesis. Among other parameters, changes in the biological properties of the cells, their viability, migration, and proliferation processes were assessed and compared to human blood vessel endothelial cells derived from the umbilical vein. Cells were subjected to a shock wave with an energy in the range of 0.03 to 0.19 mJ/mm², a frequency of 5 Hz and a constant pressure of 1 bar in an amount of 200 strokes. The results showed a positive influence of ESWT on the biological properties of LECs, especially with regard to morphology, proliferation, migration, and gene expression. The increase in cell proliferation was reported at the levels of 0.07 and 0.09 mJ/mm². These results suggest that the use of shock wave therapy *in vivo* may stimulate lymphangiogenesis.

Animal research

The first *in vivo* research in this area was published in 2010. Kubo et al. [20] examined the influence of low-energy ESWT on lymphangiogenesis stimulation and the reduction of lymphedema in a rabbit ear model with secondary lymphedema. There were 7 rabbits used in this research. The therapy started two weeks after the surgical modeling of the ear. For 3 days a week over a period of four weeks, a shock wave with parameters constituting ~10% of the lithotripsy procedure energy (0.09 mJ/mm^2, 200 strokes) was applied. The measurements and immunohistochemical tests showed a reduction in the ear thickness and a statistically significant increase in VEGF-C and VEGFR-3 expression (LEC growth factors), and thus a significant regeneration of the lymphatic vessels.

Serizawa et al. [21] also evaluated the influence of ESWT on lymphangiogenesis. In this study, a secondary lymphedema model in a rat tail preparation was used. The study was conducted on 90 rats, half of which were the test group and half the control group. The therapy included 4 treatment sessions at 3, 5, 7, and 9 days after the procedure. 500 shock wave strokes with an energy of 0.25 mJ/mm^2 were delivered. Among others findings, an increase of VEGF-C and bFGF was reported and, as a consequence, a reduction in lymphedema was observed.

Korean scientists led by Kim In Gul [22] combined ESWT with a VEGF-C hydrogel therapy for the treatment of secondary lymphedema in the lower limbs of mice. Young female mice were divided into the following 5 groups (n=5 each):normal group, group with ESWT, group with hydrogel, ESWT and hydrogel group, and control group (with lymphedema, without intervention). The surgical procedures were conducted every 3 days over a period of 4 weeks. The parameters of the wave were as follows: 500 wave strokes at an energy of 0.05 mJ/mm^2 and a frequency of 3 strokes/second. Use of the combination therapy with VEGF-C hydrogel and ESWT significantly increased VEGF-C and VEGFR3 expression and lymphangiogenesis, and the reduced lymphedema, when compared to the other groups.

Case reports

Kim-So-Yeon et al. [23] carried out research on two female patients who underwent a sparing mastectomy followed by chemo-radiotherapy. The applied treatment resulted in the occurrence of stage 3 lymphedema in both women with the dissection of the axillary lymph nodes. The treatment consisted of ESWT with an energy in the range of 0.04–0.069 mJ/mm^2, a frequency of 5 Hz and 2000 strokes, divided by 1000 in the area of the largest circumference of the upper limb, and 1000 for the surrounding issues. The intervention was performed twice a week for 8 weeks. In one of the patients, bandaging was continued throughout the treatment. In order to determine the effects of the therapy, a computer tomograph was used, and the volume and structure of tissues in the upper limb were assessed. A reduction in lymphedema was observed in both patients. In the first patient, the total volume of the upper limb decreased by 4,904 mm^3, while in the second patient the difference was 54.4 mm^3.

Clinical tests

The first pilot studies on the effects of ESWT on secondary lymphedema associated with breast cancer in female patients were conducted by Bae et al. [24]. This study included 7 women divided into two groups. In group A (n=4), manual lymphatic drainage, pneumatic compression and ESWT were used, while in group B (n=3) only the shock wave therapy was used. The therapy was administered twice a week for two weeks. The upper limb affected by lymphedema was subjected to shock waves with an energy range of 0.056–0.068 mJ/mm^2, depending upon the patients' individual feelings. In a single intervention there were 2000 strokes used. The subjective and objective measurements suggested that ESWT reduced the secondary lymphedema related to breast cancer. However, no significant differences were found between the two study groups.

Hesham et al. [25] investigated the influence of ESWT on mild-to-moderate lymphedema associated with breast cancer. Forty postmenopausal women aged 48–60 were included in the research. Additional inclusion criteria were unilateral breast cancer treated by radical mastectomy or lumpectomy, and the use of radiotherapy or chemotherapy. The patients were randomly assigned to two study groups. A traditional physiotherapy program that included cardiovascular exercises combined with the elevation of the upper limb affected by edema, manual lymphatic drainage and bandaging was carried out in both groups. A single therapy session lasted 45 minutes and took place 3 times a week for a period of 8 weeks. Additionally, in one of the groups, the patients were subjected to shock wave therapy with 2500 strokes, a pressure of 2 Ba, and a frequency of 4 Hz. The ESWT intervention was carried out twice a week for a period of 8 weeks. Measurements of the circumference of the swollen upper limb, volume, and the range of motion were performed before the start of the therapy, four weeks following the start, and after the end of treatment process. The results showed a significant improvement in all the parameters tested in the group of patients who received ESWT treatment.

In another study, El-Shazly et al. [26] evaluated the influence of ESWT on second and third stage secondary unilateral lymphedema. Sixty women aged 30–50 who had a modified mastectomy or lumpectomy, as well as radiotherapy and chemotherapy, were included in the study. Volumetric and range of motion measurements were performed before the start of the therapy. The patients were then assigned to two groups: study and control. In group A (n=30), ESWT was used twice a week for a period of six weeks. Also, a traditional physiotherapeutic program was performed for 60 minutes, three times a week. The women were subjected to shock waves with an energy of 0.004–0.069 mJ/mm^2, a frequency 5 Hz, and 2000 strokes. For group B (n=30), only the traditional physiotherapeutic program that included circulatory exercise of the upper limb affected by lymphedema, manual lymphatic drainage and pneumatic compression was applied. After the end of the therapy, measurements were taken again. The results showed an improvement in all parameters in both sample groups. However, the results were better in the group with ESWT as compared to the control group.

In a prospective pilot clinical trial, Cebicci et al. [27] evaluated the influence of ESWT on secondary unilateral lymphedema associated with breast cancer. The research involved 11 women who completed radiotherapy or chemotherapy within the last 6 months. In all patients, a shock wave therapy with a frequency of 4 Hz, 2 Ba pressure, and 2500 strokes was used. The intervention was carried out 3 times a week over a period of 4 weeks. The assessment was based on volumetric measurements. The patients also completed two questionnaires, including a shortened questionnaire on hand, shoulder, and upper limb disabilities, and a shortened questionnaire designed by the World Health Organization on the quality of life. Assessments were carried out at the beginning of the therapeutic process, after its completion, as well as one, three and six months after the treatment. The results showed a statistically significant reduction in volumetric measurements and an improvement in the questionnaire results, lasting for 6 months from the end of the treatment process.

A prospective, randomized, controlled single-blind study was also conducted by Abdelhalim et al. [28]. This study investigated the effects of ESWT and intermittent pneumatic compression therapy (IPCT) on unilateral lymphedema related to breast cancer. The study included 43 women aged 45–55 after mastectomy or lumpectomy. The patients were randomly assigned to two groups. In group 1 (n=21), ESWT was performed using an energy of 90 mJ, a frequency 4 Hz, and 2500 strokes in a single session. The intervention was conducted 3 times a week for 4 weeks. In group 2 (n=22), IPCT was performed for 45 minutes with a pressure of 60mmHg. This therapy was conducted 5 times a week for 4 weeks. In addition, all women performed home physiotherapy throughout the treatment period, which consisted of active and pumping exercises combined with the elevation of the upper limb. All patients were also asked to carry out proper hygiene and skin care. Both before and after the start of the therapy, measurements of the circumference of the upper limb, the thickness of the skin fold, and the strength of the hand grip were taken. After the treatment was completed, the researchers noted the same improvement in grip strength in both sample groups. In addition, there was a greater improvement in circumference and skinfold thickness in the ESWT group as compared to the IPCT group.

Another prospective and randomized study was carried out by LeeKyeongWooi et al. [29], who assessed the influence of ESWT on stage 2 lymphedema. This experiment included 30 women who had undergone modified radical mastectomy and chemotherapy or radiotherapy. An additional inclusion criterion was a greater than 2 cm difference in the circumference of the upper limb affected by lymphedema compared to the unaffected limb, as well as an upper limb volume greater than 200 ml. The patients were randomized into two groups. All patients conducted exercises and drainage positions, and received manual lymphatic drainage, bandaging, and proper skin care. One group received the shock wave therapy at an energy of 0.056–0.068 mJ/mm^2 with 2500 strokes, twice a week for a period of 3 weeks. Both before the start of the therapy and after its end, measurements were performed, including scoring on a visual analog scale, volumetric and upper limb circumference measurements, skinfold thickness using a caliper, a quick upper limb, shoulder and arm disability questionnaire, and a bioelectric impedance test to assess the ratio of extracellular water to total water in the body. The researchers observed an improvement in all parameters in both study groups. However, statistically significant differences were only observed in the ESWT group, and they were related to the volume of the upper limb, the circumference of the upper limb below the elbow, the thickness of the skin fold, and the water content ratio.

In 2020, there was pilot study published by Joss et al. [30] that evaluated whether low energy ESWT was effective in treating secondary lymphedema in its final stage. The study involved ten adult patients (nine women and one man) who underwent surgical treatment of lymphedema and therapy with traditional physiotherapeutic methods. All patients were treated with ESWT at a frequency of 4 Hz, an energy of 0,10 mJ/mm^2 and 2500 strokes within one therapeutic session. The treatment consisted of 8 sessions, twice a week for a period of 4 weeks. The results showed a statistically significant reduction in circumference and a slight reduction in the affected upper limb's volume. Furthermore, the researchers observed an improvement in the patients' subjective perception.

DISCUSSION

The use of shock wave treatment in lymphedema after breast cancer is an innovative approach. As such, the number of studies focusing on this subject is very limited. Hence, the works that were included in the current review are mainly animal experiments and case studies. Also taken into consideration were the available clinical tests. The majority of these clinical trials could be considered pilot studies, and were also relatively low in number (the average PEDro score was 5).

Among the scientifically proven methods for reducing upper and lower limb lymphedema, IPCT, manual lymphatic drainage, compression therapy, and kinesiotherapeutic activities are considered effective, and together have been termed comprehensive anti-edema therapy. Compression therapy is the most well studied treatment in edema management. The effectiveness of this therapy is supported by a high quality of scientific evidence obtained from many randomized clinical tests, meta-analyses, and systematic reviews. Vignes [31] has indicated that compression therapy should serve as the basis of comprehensive lymphedema therapy, an approach supported by many other authors [32,33,34]. Leung et al. [35], after reviewing the literature, concluded that compression therapy effectively reduces the volume of the affected limb. Also, a group of experts led by Rabe et al. [36] recommend compression as one of the most effective, clinically confirmed methods of lymphedema treatment.

The usefulness of IPCT in lymphedema treatment has also been shown in numerous clinical studies. Yüksel et al. [34], after conducting an analysis of scientific evidence in the field of conservative lymphedema treatment, reported a high effectiveness for IPCT, including for the treatment of BCRL. These conclusions have also been confirmed by the Franks team's review [37].

Manual lymphatic drainage is another method applied in anti-edema therapy. Huang et al. [38] published a meta-analysis assessing this method and showed a low effectiveness for this intervention as an exclusive therapy. On the other hand, Ezzo et al. [39] examined the effectiveness of manual lymphatic drainage as an element of comprehensive therapeutic management. The results of this analysis emphasized the necessity to use several therapeutic methods simultaneously, while paying attention to the effectiveness of manual lymphatic drainage as a supplement to compression treatment.

Rogan et al. [7] conducted an extensive review of the literature regarding therapeutic options applied for secondary lymphedema therapy in patients after breast cancer. This study, in particular, assessed the influence of physical exercises, and clearly indicated the effectiveness of this rehabilitation form. Indeed, there are numerous scientific reports recognizing targeted physical exercises as a necessary element of comprehensive anti-edema therapy. The necessity to perform early compression therapy and select appropriate exercises, especially ones focusing on the stimulation of the muscle pump, is emphasized [32,40,41]. In addition, researchers have questioned the validity of the over 20-year-old belief that a physical strain of the affected upper limb may intensify the existing problem or create new issues. The latest meta-analysis carried out by Hasenoehrl and his team [42] focused on evaluating the impact of resistance exercises on BCRL, and upper and lower limb muscle strength. The results showed that resistance exercises do not have a negative influence on the edema and, in some cases, even lead to its reduction. The authors, however, indicate that further research is needed to determine, among others things, the standards for such procedures.

To date, research indicates that the combination of several proven, above-mentioned treatments into a comprehensive lymphedema therapy brings the greatest health effects. The results of this review indicate the potential in the use of shock wave treatment, not necessarily as a form of monotherapy, but as part of a complex anti-edema therapy protocol in patients after breast cancer.

Work limitations

Above all, it should be emphasized that this work is not a classic systematic review. Prospectively, a meta-analysis of randomized clinical trials would be of much greater value, However, the number of studies is currently not enough for such an analysis. In addition, the current literature review was carried out by two authors. In order to increase the reliability of such research, a team of experts who would apply appropriate study evaluation blinding processes should be appointed. Nonetheless, as this is relatively new therapy and currently available reports indicate the need for further clinical trials, a preliminary review of this nature is warranted.

CONCLUSIONS

Analysis of the cited articles suggests that shock wave therapy is a promising tool for the treatment of secondary lymphedema, including lymphedema in patients after breast cancer treatment. As the number of studies is still quite low, further clinical tests should be conducted to confirm the current reports and to determine the most effective treatment parameters for this therapy.

References

1. Torre LA, Islami F, Siegel RL, Ward EM, Jemal A. Global cancer in women: burden and trends. Cancer Epidemiol Biomarkers Prev 2017; 26(4): 444-457.
2. Valentina A, Silvia J, Dutil J, Fejerman L. Genetic epidemiology of breast cancer in Latin America. Genes Basel 2019; 10(2): 153.
3. Lundqvist A, Andersson E, Ahlberg I, Nilbert M, Gerdtham U. Socioeconomic inequalities in breast cancer incidence and mortality in Europe: a systematic review and meta-analysis. Eur J Public Health 2016; 26(5): 804-813.
4. Peart O. Breast intervention and breast cancer treatment options. Radiol Technol 2015; 86(5): 535-558.
5. De Vrieze T, Nevelsteen I, Thomis S, De Groef A, Tjalma WAA, et al. What are the economic burden and costs associated with the treatment of breast cancer-related lymphoedema? A systematic review. Support Care Cancer. 2020 Feb; 28(2): 439-449. DOI: 10.1007/s00520-019-05101-8. Epub 2019 Oct 28. PMID: 31656987.
6. Dayan JH, Ly CL, Kataru RP, Mehrara BJ. Lymphedema: pathogenesis and novel therapies. Annu Rev Med 2018; 69: 263-276.
7. Rogan S, Taeymans J, Luginbuehl H, Aebi M, Mahnig S, et al. Therapy modalities to reduce lymphoedema in female breast cancer patients: a systematic review and meta-analysis. Breast Cancer Res Treat 2016; 159(1): 1-14.
8. Taradaj J, Halski T, Rosińczuk J, Dymarek R, Laurowski A, et al. The influence of kinesiology taping on the volume of lymphoedema and manual dexterity of the upper limb in women after breast cancer treatment. Eur J Cancer Care Engl 2016; 25(4): 647-60.
9. Vignes S. Lymphedema: from diagnosis to treatment. Rev Med Interne 2017; 38(2): 97-105.
10. Carl HM, Walia G, Bello R, Clarke-Pearson E, Hassanein AH, Cho B, et al. Systematic review of the surgical treatment of extremity lymphedema. J Reconstr Microsurg 2017; 33(6): 412-425.
11. Smoot B, Chiavola-Larson L, Lee J, Manibusan H, Allen DD. Effect of low-level laser therapy on pain and swelling in women with breast cancer-related lymphedema: a systematic review and meta-analysis. J Cancer Surviv 2015; 9: 287–304.
12. Robijns J, Censabella S, Bulens P, Maes A, Mebis J. The use of low-level light therapy in supportive care of patient with breast cancer: review of the literature. Lasers Med Sci 2017; 32(1): 229-242.
13. Kasawara KT, Mapa JMR, Ferreira V, Added MAN, Shiwa SR, et al. Effects of Kinesio Taping on breast cancer-related lymphedema: a meta-analysis in clinical trials. Physiother Theory Pract 2018; 34(5): 337-345.
14. Liao CD, Xie GM, Tsauo JY, Chen HC, Liou TH. Efficacy of extracorporeal shock wave therapy for knee tendinopathies and other soft tissue disorders: a meta-analysis of randomized controlled trials. BMC Musculoskelet Disord 2018; 19(1): 278.
15. van der Worp H, van den Akker-Scheek I, van Schie H, Zwerver J. ESWT for tendinopathy: technology and clinical implications. Knee Surg Sports Traumatol Arthrosc 2013; 21(6): 1451-1458.
16. Schmitz C, Császár NB, Milz S, Schieker M, Maffulli N, et al. Efficacy and safety of extracorporeal shock wave therapy for orthopedic conditions: a systematic review on studies listed in the PEDro database. Br Med Bull 2015; 116(1): 115-38.
17. Storheim K, Gjersing L, Bølstad K, Risberg MA. Extracorporeal shock wave therapy (ESWT) and radial extracorporeal shock wave therapy (rESWT) in chronic musculoskeletal pain. Tidsskr Nor Laegeforen 2010; 130(23): 2360-2364.
18. Schaupper M, Jeltsch M, Rohringer S, Redl H, Holnthoner W. Lymphatic vessels in regenerative medicine and tissue engineering. Tissue Eng Part B Rev 2016; 22(5): 395-407.
19. Rohringer S, Holnthoner W, Hackl M, Weihs AM, Rünzler D, et al. Molecular and cellular effects of in vitro shockwave treatment on lymphatic endothelial cells. PLoS One 2014; 9(12): e114806.
20. Kubo M, Li TS, Kamota T, Ohshima M, Shirasawa B, et al. Extracorporeal shock wave therapy ameliorates secondary lymphedema by promoting lymphangiogenesis. J Vasc Surg 2010; 52(2): 429-434.
21. Serizawa F, Ito K, Matsubara M, Sato A, Shimokawa H, et al. Extracorporeal shock wave therapy induces therapeutic lymphangiogenesis in a rat model of secondary lymphoedema. Eur J Vasc Endovasc Surg 2011; 42(2): 254-260.
22. Kim IG, Lee JY, Lee DS, Kwon JY, Hwang JH. Extracorporeal shock wave therapy combined with vascular endothelial growth factor-C hydrogel for lymphangiogenesis. J Vasc Res 2013; 50(2): 124-133.
23. Kim SY, Bae H, Ji HM. Computed tomography as an objective measurement tool for secondary lymphedema treated with extracorporeal shock wave therapy. Ann Rehabil Med. 2015; 39(3): 488-493.
24. Bae H, Kim HJ. Clinical outcomes of extracorporeal shock wave therapy in patients with secondary lymphedema: a pilot study. Ann Rehabil Med 2013; 37(2): 229-234.
25. Hesham GM, Ali AT. Extracorporeal shockwave therapy for post-menopausal patients with breast cancer- related lymphedema. Int J Cancer Clin Res 2015; 49(1): 1618-1625.
26. El-Shazly M, Borhan WH, Thabet WN, Hassan A. Response of post-mastectomy lymphedema to extracrorporeal shockwave therapy. Journal of Surgery 2016; 4(3): 14-20.
27. Cebicci MA, Sutbeyaz ST, Goksu SS, Hocaoglu S, Oguz A, et al. Extracorporeal shock wave therapy for breast cancer-related lymphedema: a pilot study. Arch Phys Med Rehabil2016; 97(9): 1520-1525.
28. Abdelhalim NM, Samhan AF. Comparison of extracorporeal shock waves therapy versus intermittent pneumatic compression therapy in breast cancer-related lymphedema. Int J Cancer Clin Res 2018; 14(2): 77-85.
29. Lee KW, Kim SB, Lee JH, Kim YS. Effects of extracorporeal shockwave therapy on improvements in lymphedema, qual-

ity of life, and fibrous tissue in breast cancer-related lymphedema. Ann Rehabil Med 2020; 44(5): 386-392.

30. Joos E, Vultureanu I, Nonneman T, Adriaenssens N, Hamdi M, et al. Low-energy extracorporeal shockwave therapy as a therapeutic option for patients with a secondary late-stage fibro-lymphedema after breast cancer therapy: a pilot study. Lymphat Res Biol 2020; 19(2). DOI: 10.1089/lrb.2020.0033.

31. Vignes S. Lymphedema: from diagnosis to treatment. Rev Med Interne. 2017; 38(2): 97-105.

32. Leung EY, Tirlapur SA, Meads C. The management of secondary lower limb lymphoedema in cancer patients: a systematic review. Palliat Med 2015; 29(2): 112-119.

33. Rabe E, Partsch H, Hafner J, Lattimer C, Mosti G, Neumann M, et al. Indications for medical compression stockings in venous and lymphatic disorders: an evidence-based consensus statement. Phlebology 2018; 33(3): 163-184.

34. Yüksel A, Gürbüz O, Velioğlu Y, Kumtepe G, Şenol S. Management of lymphoedema. Vasa 2016; 45 (4): 283-291.

35. Franks PJ, Moffatt CJ. Intermittent pneumatic compression devices in the management of lymphedema. JAMA Dermatol 2015; 151(11): 1181-1182.

36. Huang TW, Tseng SH, Lin CC, Bai CH, Chen CS, Hung CS, et al. Effects of manual lymphatic drainage on breast cancer-related lymphedema: a systematic review and meta-analysis of randomized controlled trials. World J Surg Oncol 2013; 11: 15.

37. Ezzo J, Manheimer E, McNeely ML, Howell DM, Weiss R, Johansson KI, et al. Manual lymphatic drainage for lymphedema following breast cancer treatment. Cochrane Database Syst Rev 2015; (5): CD003475.

38. Singh B, Disipio T, Peake J, Hayes SC. Systematic review and meta-analysis of the effects of exercise for those with cancer-related lymphedema. Arch Phys Med Rehabil 2016; 97(2): 302-315.

39. Kayıran O, De La Cruz C, Tane K, Soran A. Lymphedema: from diagnosis to treatment. Turk J Surg 2017; 33(2): 51-57.

40. Panchik D, Masco S, Zinnikas P, Hillriegel B, Lauder T, Suttmann E, et al. Effect of exercise on breast cancer-related lymphedema: what the lymphatic surgeon needs to know. J Reconstr Microsurg 2019; 35(1): 37-45.

41. Hasenoehrl T, Palma S, Ramazanova D, Kölbl H, Dorner TE, Keilani M, et al. Resistance exercise and breast cancer-related lymphedema-a systematic review update and meta-analysis. Support Care Cancer 2020; 28(8): 3593-3603.

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