Title: Measuring change in breast cancer related lymphoedema during reflexology: an exploratory study using thermal imaging.

Abstract

Background

Reflexology lymph drainage (RLD) for breast cancer related lymphoedema (BCRL) may have a positive impact on arm swelling and pain. Thermal imaging is a means of tracking temperature change by visual images.

Aims

To explore the use of thermal imaging in treatment for BCRL.

Method

The swollen arms of two participants with BCRL were photographed using a thermal imaging camera during a single RLD treatment. Limb Volume Circumferential Measurement (LVCM) of both arms was taken before, after and the next day. The images were examined for visual changes, and temperature data were extracted.

Findings

Images showed differences in temperature within the affected hand and arm over 45 minutes. LVCM data indicated a loss of limb volume in the affected arm in both cases, which continued to decrease over 24 hours.

Conclusion

Thermal imaging may be useful in tracking temperature change during treatment for BCRL.

1. Introduction

Breast Cancer Related Lymphoedema

Breast cancer related lymphoedema (BCRL) is a consequence of treatment for breast cancer in an estimated 1 in 5 patients (DiSipio *et al.*, 2013). It occurs when treatment for breast cancer has caused damage to the vessels or lymph nodes in and around the axilla, resulting in retained fluid in the arm, chest or shoulder. It is a condition which significantly alters functionality, body image and quality of life (Whatley, Street and Kay, 2018; Thomas and Job, 2018; Taghian *et al.*, 2014)

Treatment strategies remain controversial, although there is broad agreement that a multi-disciplinary approach achieves the best results for the patient**.** (Rooney, Cooper-Stanton and Cave-Senior, 2018; Rodríguez Manso *et al.*, 2018; Lymphoedema Framework, 2006)

Current treatment modalities for BCRL include the wearing of compression garments, gentle exercise and the use of manual lymphatic drainage (MLD). MLD is a process of gentle massage which encourages retained fluid to move into unaffected tissue. There is some evidence to suggest that compression garments are most useful in the maintenance phase of lymphoedema (Rabe *et al.*, 2018). However, it appears that some women discontinue their use of the garments for a variety of reasons including body image concerns (Longhurst, Dylke and Kilbreath, 2018). There is broad agreement that more conservative treatment modalities are necessary for targeting this distressing condition.

Reflexology

Complementary therapies are commonly found in cancer care (Harris *et al.*, 2012). Of these, one of the most popular is reflexology, which is considered to have a range of benefits for quality of life in this patient group (Wyatt *et al.*, 2012; Hodgson, 2000; Stephenson, Weinrich and Tavakoli, 2000). Reflexology involves following treatment protocols applying pressure to the foot and hand. It is thought to have a profound effect on the relaxation of the patient and there is an emerging evidence base indicating that other benefits may result from treatment (Green *et al.*, 2010; Woodward, Norton and Barriball, 2010; Hughes, Smyth and Lowe-Strong, 2009; Siev-Ner *et al.*, 2003).

The reflexology technique explored here is called reflexology lymphatic drainage or RLD. It is an adapted protocol which closely follows the pattern of manual lymphatic drainage (MLD) commonly used in treatment for BCRL, except that the reflexes of the feet presumed to relate to areas of the body are worked upon instead of the areas of the chest, arms and shoulders.

A recent study which examined the use RLD on breast cancer related lymphoedema designed to draw fluid up from the affected arm into the chest and abdomen (Whatley *et al.*, 2016) showed there was a significant decrease in swelling in the affected arm after a series of four reflexology treatments administered weekly. Limb volume measurements indicated improvement in all 26 participants, and qualitative data supported corresponding reductions in pain and swelling, improvements in functionality and body confidence, and re-engagement with usual activities (Whatley, Street and Kay, 2018).

During this study, participants frequently commented on sensations of change in temperature as retained fluid began to move through the affected arm and into the

neck and chest. It was decided to explore this reported temperature change by taking thermal images of the subject whilst RLD was conducted. The premise being that the thermal camera would facilitate a means of tracking changes in fluid and temperature.

Thermal Imaging

Thermal imaging is a technology commonly used in visualising heat patterns and identifying the source of heat emissivity. Whilst it is most commonly used in engineering and in fire rescue contexts, its use is emerging in medical and research applications. (Owen, Ramlakhan and Saatchi, 2018; Petrova *et al.*, 2018; Godoy *et al.*, 2017)

2. Method

Aim

The aim of this study was to explore the temperature change in the affected arm in 2 participants with breast cancer related lymphoedema during a single treatment of reflexology lymph drainage.

Ethical Approval

All procedures performed in this study were in accord with the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments. Permission for the research was granted by the University ethics committee and written, informed consent was obtained from both participants.

Sample

Inclusion criteria

A convenience sample of two participants over the age of 18 years were recruited to the study. Participants were included if they had undergone surgery for breast cancer, along with axillary lymph node dissection and had developed secondary lymphoedema in one arm. Women who had undergone a double mastectomy were excluded.

Procedure

Participants were provided with a detailed information sheet outlining the aims of the study and the treatment protocol. Both participants gave informed consent after having the opportunity to ask questions. They underwent a consultation with a reflexology practitioner where they were asked about their general health in accord with the AoR (Association of Reflexologists) professional body code of practice and ethical guidelines. Both participants were in good health.

Treatment protocol

Each of the participants received a single reflexology lymphatic drainage (RLD) treatment from a qualified RLD reflexologist. The RLD protocol included 30-40 minutes of stimulation to specific zones on both feet. The reflex areas corresponding to the lymphatic and renal systems were worked, firstly on the foot ipsilateral with the unaffected, *normal* arm using a range of finger and thumb techniques. The same sequence was then performed on the other foot corresponding to the *swollen* arm and, finally, the sequence was repeated on the first foot. Both participants continued to receive their usual care from their lymphoedema service providers, and followed their usual pattern of compression sleeve wear.

Data Collection

LVCM

The participants' arms were both measured using the Limb Volume Circumferential Measurement (LVCM) technique. This is the most commonly used method in the UK (Franks, Williams and Moffatt, 2006) and comprised measuring circumferences starting 2cm above the wrist joint and then at 4cm intervals as far as the axilla. These measurements were then used to calculate the volume of the limb as a cylinder. Other measurement techniques such as water displacement and Perometry were deemed impractical for this exploratory study but these are regarded as the standard method for accurate measurement of limb volume (Jain, Danoff and Paul, 2010).

Thermal imaging

A FLIR (A35c) thermal imaging camera was used to photograph the affected arm during the reflexology treatment, a duration of between 30 and 40 minutes. The camera images were uploaded a laptop, where images were stored for temperature analysis.

Data Analysis

Limb Volume

Using LVCM, arm volumes were calculated and compared with one another, the unaffected arm acting as the control. The difference between the two arms was then compared before and after treatment to obtain a volume difference. A percentage volume difference was then calculated to express the excess volume in the larger

arm as a percentage of the volume of the normal arm. The same process was used to compare arms 24 hours later.

Thermal Images

For each individual, images of the affected arm were examined for visual differences in heat emissivity. The FLIR software allows for a colour palette which can illustrate differences in temperature. A deeper colour indicates a higher temperature, a paler colour indicating a lower temperature. As the colour palette highlights areas of difference, these can be measured for temperature using cursor points.

Temperature measurement

Using the colour images as a guide, temperature measurements were taken using the FLIR (A35c) software) at three points where the visual appeared to alter the most. The software allowed the use of a cursor point on the image taken. This could then be pinpointed in the next image producing a series of temperature measurements at each point of interest. This varied by subject as each one had a slightly different pattern of lymphoedema.

For comparison purposes it was decided to focus on the hand, forearm and abdomen to explore whether fluid movement and associated temperature changes could be detected during the RLD treatment.

3. Results

Participant 1 had been diagnosed with lymphoedema in 2011 and was affected on the right arm, primarily in the hand and forearm area. Participant 2 had been diagnosed in 2010 and was mostly affected in the left hand, forearm and upper arm.

Both participants were reflexology naïve and had different patterns of compression sleeve wearing. Participant 1 rarely wore her garment, finding it uncomfortable and unattractive, Participant 2 wore her compression sleeve daily.

Limb volumes

LVCM was carried out to measure both arms as cylinders. The percentage volume difference between the two arms was then calculated. This measurement was conducted prior to the RLD treatment, immediately after, and 24 hours afterwards.

An improvement in the volume difference was seen in both participants, which continued over the following 24 hours. (Figure 1.)

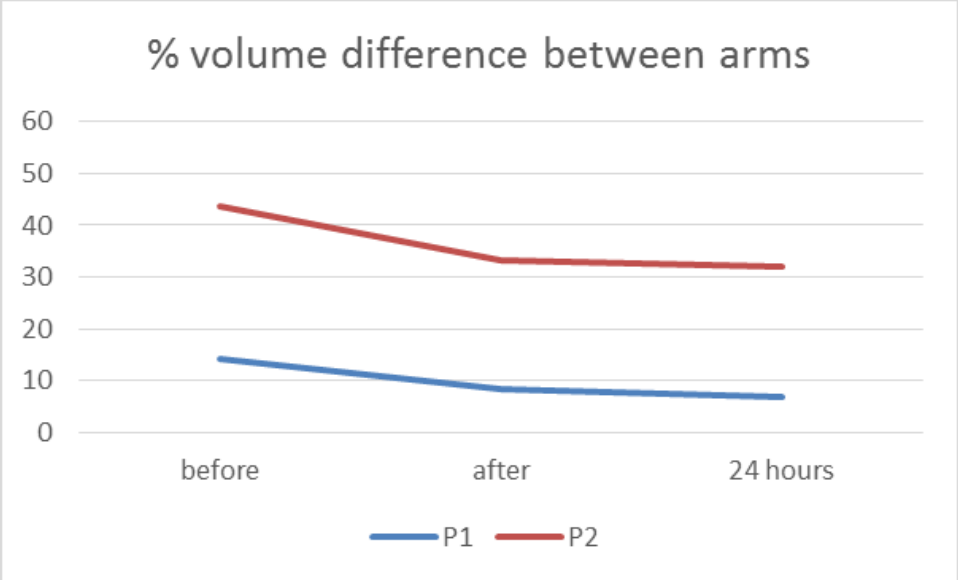

Figure 1. Percentage volume difference

Participant P1

Images

The images illustrated here show heat in the hand and fingers at the start, reducing at mid point, and dissipating further at the end of the treatment session. The abdomen shows more heat emissivity at the end of the session (Figure 4) than at the start (Figure 2).

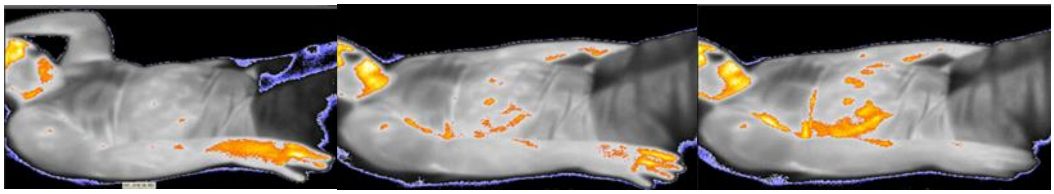

Figure 2. **Figure 3.** **Figure 4**

Temperature P1

In the case of participant 1, temperatures in the hand initially rose then fell sharply over a period of 32 minutes, a temperature difference of 1.79 degrees (Figure 5.) Temperatures in the forearm fluctuated before dropping away. This may be an indication that fluid from the hand is moving up the arm as it tracks towards the axilla area, thus changing the temperature emissivity captured on the thermal image. During the same period, we saw the abdominal temperature rise.

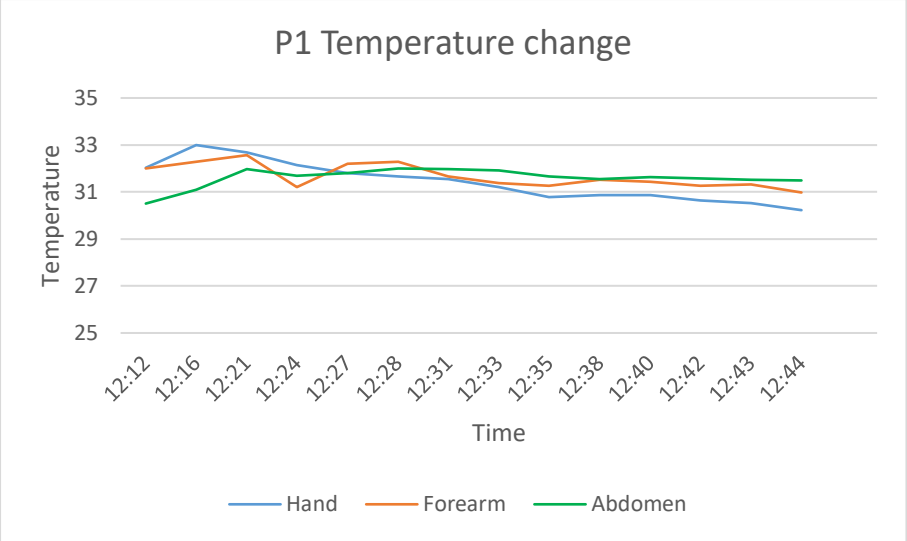

Figure 5. **Participant 1 Temperature change during RLD**

Participant P2

Images

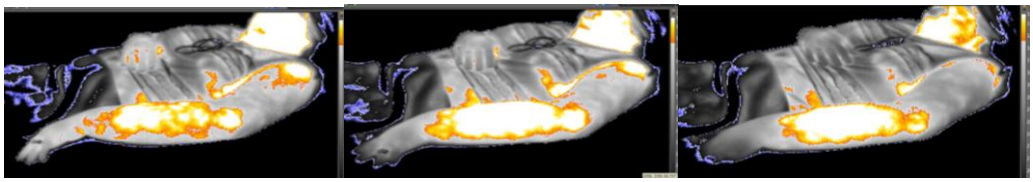

Figure 6. **Figure 7.** **Figure 8.**

The images taken over a 32 minutes interval indicated areas of heat in the wrist, forearm and shoulder. Half way through the treatment, the thermal image indicated a deepening of colour at the forearm, (Figure 7) and a larger spread of heat, extending right across the forearm. By the end of the treatment (Figure 8) this area of heat had become smaller end to end but was still as intense in colour. Heat in the wrist did not

appear at the end. The heat in the shoulder area appeared less visible at the mid way point, and was almost gone at the end.

Temperature P2

In participant 2, temperatures in the hand started to fall within a few minutes, then continued to fall by 5.7 degrees over a period of 33 minutes. Temperatures in the forearm rose within 10 minutes finishing at 1.8 degrees above where they were at the start of the experiment, whilst abdominal temperatures remained fairly static. (Figure 9).

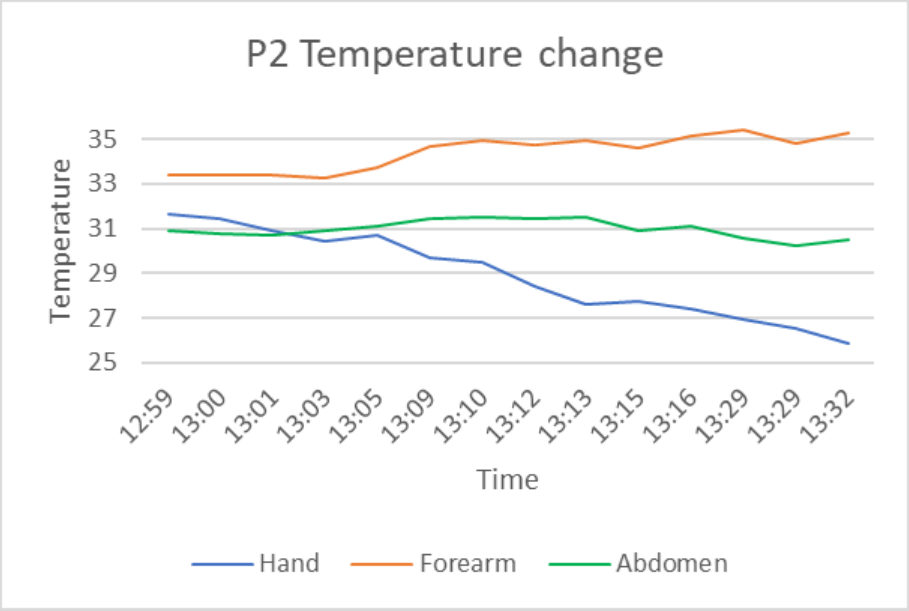

Figure 9. **Participant 2 Temperature change during RLD**

4. Discussion

Working with patients with BRCL using manual lymphatic drainage (MLD) focuses on drawing fluid up the affected arm in a specific and highly skilled technique of massage. Drawing fluid into the neck and chest area helps to activate the mechanisms of lymphatic drainage and allow the trapped lymph to be moved to undamaged areas to be processed in the normal way by the lymphatic and renal systems.

Reflexology lymphatic drainage mimics the pattern of MLD but through usage of the foot reflexes thought to correspond to the discrete body areas involved (neck, shoulder, chest etc).

The pattern of temperature change shown in the images suggests movement of fluid from hand into forearm and up into the shoulder, neck and chest. Increases in temperature in the forearm can be seen in P2 who had a long standing issue in this area, which was not maintained by regular wearing of compression garments. The pattern of fluid movement in P1 differed. Changes in heat emissivity can be seen from the fingers and hand into the forearm and up in to the chest and abdomen. This participant did not have a long standing problem and was a consistent wearer of her compression sleeve.

It is possible that the temperature changes in P1 occurred because of the removal of the compression sleeve shortly before treatment began. Further research into temperature changes during wear, immediately after wear and later on after a short period of non wear might allow further insight into this.

Both participants were lying in a relaxed supine position for 40 minutes whilst the experiment took place. The affected arm was mostly resting on a couch arm for this

period, it is feasible that temperature changes are a natural consequence of this. Controlled experiments would be needed to rule this out.

This pilot study was designed to explore the usefulness of thermal imaging technology in tracking temperature change in the swollen limb in real time as reflexology lymphatic drainage treatment was applied. Limb volume measurements indicated that fluid reduction occurred immediately after treatment, and this appeared to continue the following day. Previous research has used a series of reflexology sessions, and a cumulative effect of fluid drainage was reported which was sustained over several months. (Whatley, 2016). We might speculate therefore that further treatment may have yielded a greater effect.

Thermal imaging appears useful for visualising the temperature changes which accompany fluid movement as it tracks up the arm to shoulder, neck and abdomen. Once fluid reaches this area it is probable that lymphatic processing continues in the normal way, and excess fluid is transported to the renal system to be excreted as necessary.

Wearing of compression sleeves has an influence over retained fluid and the corresponding temperature of the arm. One of the participants (P1) was a consistent sleeve wearer, rarely opting to go without it for fear of worsening the issue. However this seemed to push the fluid into the hand and she was less keen to wear a compression glove. P2 was reluctant to wear a compression sleeve at all, and her issue was in the forearm, where retained fluid had hardened over time.

Patient adherence to wearing compression garments is thought to be affected by a range of factors. Wearing the garments is influenced by fear of worsening the condition, whilst the discontinuation of wear is thought to be influenced by body

image concerns (Longhurst, Dylke and Kilbreath, 2018). In these two participants different wearing patterns were evident.

Thermal images indicate that a softer pattern of fluid was evident in P1 (the consistent sleeve wearer) than in P2 who rarely wore a sleeve. Wearing of compression garments is thought to aid in the maintenance of lymphoedema but is less effective for prevention (Rabe *et al.*, 2018).

Research suggests that lymphoedema is more common than had been previously recognised, and treatment developments have not kept pace with demand (Keeley, 2017). However, more recent advances in the treatment of BCRL suggest that a sustainable solution could be found for this debilitating problem. A recently explored treatment option for BCRL is micro surgery to increase fluid movement (Khan *et al.*, 2019) but the cost implications of lymphaticovenous anastomosis are likely to be more burdensome than less invasive approaches. It is also a technique which is not suitable for all sufferers.

A lack of research into BCRL hinders our understanding of impact on quality of life of therapeutic interventions like manual lymphatic drainage (Müller *et al.*, 2018). More research needs to be conducted to explore the long term costs of lymphoedema and the cost benefit of a wide variety of treatments. A German study found that mean annual costs for lymphoedema treatment were over 5700 euros(Gutknecht *et al.*, 2017) .

It is possible that targeting the specific pattern of lymphoedema in the individual is more effective than generic treatment protocols (De Vrieze *et al.*, 2018). This type of reflexology lymphatic drainage is a targeted protocol adapted to the individual’s pattern of fluid retention, as is MLD.

The mechanism of action for reflexology remains largely unexplored, and it is first imperative that any reported effects are measured closely, before developing robust research to monitor these changes and test for safety as well as efficacy.

The reported reduction in retained fluid in previous studies was replicated here, suggesting that were this technique to be used for lymphoedema it may also be a relatively low cost and sustainable method for managing the problem. In previous studies several sessions of reflexology were applied weekly over a month, and there was a cumulative effect of volume reduction. The fluid loss appeared to be a long term consequence, with most of the group studied maintaining the lower levels of fluid over many months.

Limitations

This study was a pilot exploration of the usefulness of thermal imaging technology in patients with BCRL. The equipment used needed to be sensitive to tiny incremental changes in the temperature of the affected arm. This sensitive technology is costly and therefore may not be readily available to lymphoedema practitioners.

The measurement of the size of the arm as compared to the unaffected arm remained the true measurement of differences in limb volume, and the thermal images were not designed to be an arm measurement aid in this sense.

The use of reflexology lymphatic drainage as an aid to reduction of retained fluid has been demonstrated in previous studies (Whatley *et al.*, 2016) and this experiment builds on anecdotal reports of temperature changes during RLD.

Thermal imaging collects emissivity values, which are a reflection of temperature rather than actual arm temperature. In some patients, the retained fluid rests in

deeper tissues, and it is less likely that temperature changes could be captured than in those where retained fluid is in superficial tissues.

Movement of the participants was not controlled during the application of reflexology, so images may have been affected by arm movement. Any further research might seek to control this more stringently.

Further research is indicated into similar treatments such as MLD to establish comparisons of effectiveness and sustainability. The use of thermal imaging could help to compare the progress of fluid through affected limbs to establish where treatment could be focused.

5. Conclusion

RLD may be a useful means of managing fluid retention in some individuals with BCRL, reducing temperature and promoting a more comfortable arm with corresponding improvements in shoulder morbidity.

Opinion suggests that a multi-disciplinary approach is the most effective means of treatment of BCRL (Rooney, Cooper-Stanton and Cave-Senior, 2018; Rodríguez Manso *et al.*, 2018). Reflexology lymphatic drainage appears to be a non invasive, and cost effective tool to be added to the toolbox.

The addition of thermal imaging may be a useful and non invasive means of tracking fluid movement within the arms of BCRL affected individuals with a view to developing more tailored treatment plans.

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