Measurement of Muscle Activities for Evaluating Physical Burden and Pain during Mammography Positioning

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Mammography has become widespread as a standard method for breast cancer screening. For women undergoing mammography, compression of the breast and special positioning are requested, and they cause the physical burden and pain. However, the reality of the physical burden and subjective pain associated with mammography are not fully understood. We therefore measured the muscle activity of subjects during positioning for mammography screening using surface electromyography to evaluate the physical burden and pain associated with positioning. The subjects consisted of 15 women (age: 44.4 ± 6.56 years old, height: 160 ± 6.7 cm, weight: 55.08 ± 3.94 kg, and body mass index: 21.4 ± 2.21). Measurements were performed in the mediolateral oblique position, a standard position for mammography. The target muscles were the sternocleidomastoid, biceps, trapezius and gastrocnemius muscles. A portable multi-purpose bio-amplifier was used for the measurements. Visual analogue scale (VAS), which is a tool for self-assessment of subjective pain, was used for pain measurement. The analysis of variance showed the significant difference in the amounts of muscle activities in all the target muscles between the relaxation phase before mammography positioning and the stress phase during mammography positioning. The sites with the increased muscle activities were consistent with the sites of pain measured with the VAS. These results suggest that positioning during mammography affects the muscle activity and that the increased muscle activity could be related to the pain. Understanding muscle activities during mammography is invaluable in making the pain reduction program for the subjects undergoing mammography.

Keywords: mammography; muscle activity; physical pain; surface electromyography; visual analogue scale


Mammography (MMG) is a good method for the detection of small early cancers and calcification. Its use has become widespread as a standard method for breast cancer screening in the United States, Europe and Japan. MMG is performed by compressing the breast with an X-ray transmissive plate and then pressing further to make the thickness of the breast as thin as possible for accurate diagnosis and to reduce exposure to radiation (Henrich et al. 1999). In addition to the compression of the breast, imaging is carried out in a fixed posture in which the neck is bent unnaturally and the shoulders are flexed for accurate imaging. Compression of the breast combined with the awkward posture can cause an unpleasant experience with pain for women undergoing the examination, although there is variation in the degree of discomfort. On the other hand, positioning for the MMG is actually left up to each radiological technologist based on his/her experience. For women undergoing examination, compression of the breast and special positioning are requested. When this issue is studied from the perspectives of increasing awareness and promoting breast cancer screening in support of improving women’s health, we believe the reality of the physical burden and subjective pain associated with MMG are not fully understood despite the fact that the woman’s cooperation is required.

In the literature on MMG, studies on advances in imaging equipments, appropriate imaging techniques and quality control methods for use of the equipment have been carried out (Haus 2002; Ng and Muttarak 2003; Ng et al. 2006; Yamada 2010). In addition, there have been several reports concerning the effect of pain associated with MMG on the subject’s behavior while undergoing the screening test (Kornguth et al. 1996; Sapir et al. 2003; Taguchi et al. 2010) and those concerning the subjective pain in the breast and related sites using a visual analogue scale (VAS) (Sharp et al. 2003; Hagen et al. 2008). These reports suggest that MMG causes the physical burden, mainly pain, experienced by the subjects. However, quantitative measurements and
evaluation of the burden at different sites on the body have not been performed to any significant extent. Furthermore, the association with the burden on body parts other than the breast during MMG have not been reported. In the shooting of MMG, it is important to shoot so that there are no blind areas or defects in the imaging. To that end, relaxing the tension of the body of the examinee will lead to a high quality image. However, specific methods to promote subtle adjustments and relaxation of the body when the examinee is being positioned have not been clearly indicated in guidelines (Henrich et al. 1999). In reality, it is left to the technologist based on their knowledge and experience.

In the present study, we focused on electromyography (EMG) as a physiological parameter to capture the reality of the physical burden and the subjective pain associated with MMG. EMG captures the action potential that occurs during skeletal muscle contraction as a biological signal and it is widely used to analyze body motion (De Luca 2002; Kizuka et al. 2006). In particular, surface EMG, which is measured using surface electrodes attached to the skin, is believed to provide data for quantifying the physical burden of MMG. This study focused on the muscle activity at various body sites during MMG positioning and aimed to objectively quantify the physical burden of the subjects using surface EMG, which can visualize muscle activity. In addition, our final goal is to build a care program to relieve the subjects’ pain during MMG. This study is to validate the basic data gathered towards this goal.

Subjects and Methods

Subjects

The subjects consisted of 15 women (in their 30s to 50s) without heart disease, hypertension or skin disease. The mean age of the subjects was 44.4 ± 6.56 years old (mean ± standard deviation), height was 160 ± 6.7 cm, weight was 55.08 ± 3.94 kg, and their body mass index (BMI) was 21.4 ± 2.21. The enrolled subjects were explained that female radiological technologists with advanced knowledge of MMG would perform the positioning without X-ray irradiation in the study. Written consent was obtained from all the subjects for their participation in the study.

Target muscles

Muscle activities were measured from start to finish of the MMG during mediolateral oblique (MLO) positioning for imaging. The sternocleidomastoid, biceps and trapezius muscles, which were associated with the sites showing the high degree of physical pain according to the VAS by Sharp et al. (2003) and the gastrocnemius muscle which is not related directly to the imaging, were selected for measurements (Sharp et al. 2003). Measurements were performed only on the right side of the body, while both sides of the breast were sequentially positioned for imaging. This was to compare the differences in muscle activities between the same side as the breast undergoing MMG and the opposite side.

EMG measurement

In this study, muscle activities were measured by surface electromyography (EMG) using surface electrodes attached to the skin. The apparatus used for measurement was a compact portable multi-purpose bio-amplifier. EMG sensors were placed in position using bipolar active electrodes. Electrodes were placed to the center of the uppermost margin starting from the acromion for the trapezius muscle and to the middle of the belly of the muscles for the biceps, sternocleidomastoid and gastrocnemius muscles and the ground was attached to the skin of the subject’s wrist (Fig. 1). In order to reduce the contact resistance between the skin and the electrodes, the attachment sites were wiped with a pretreatment agent (Skin Pure) and electrodes were coated with conductive paste to ensure conduction.

Subjective measurement of pain and body sites

The degree of pain during MMG was assessed using the VAS (Gould et al. 2001). The VAS consisted of a horizontal line of 10 cm with scoring in increments of 1 cm from “no pain at all” at the leftmost position (0 point) to “the worst pain you have ever felt” on the rightmost position (10 points). The subjects were asked to point with their finger to the level of pain they were feeling. An illustration of the front and back of the body was shown and the subjects were asked to point to the site where the most pain was felt. The procedure was performed at the same time as the EMG measurements and the subjects were instructed to be aware of the site where pain was felt and

![Fig. 1. Active EMG sensors placed around the target muscles.](image-url)
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The pain value during the imaging. The subject was then questioned to confirm the VAS points and the site of pain at the end of each positioning.

Measurement methods

According to the MMG method, EMG was measured during the following defined phases. The phase before positioning was defined as the Relaxation Phase (RP), the interval between the start of positioning and breast fixing was defined as the Keep Phase (KP) and the interval between breast fixing and the end of imaging was defined as the Pressure Phase (PP). After EMG measurement, the degree of subjective pain was confirmed by the VAS.

Analysis of EMG data

EMG waveform results from the number of muscle fibers involved in the muscle contraction and the potential generated by them. When the muscle activity increases, the height of the amplitude increases and when muscle activity decreases, the height decreases. The integral value (iEMG), which is the sum of the potential, is proportional to the strength of the muscle contraction, and these values were used in this study. The iEMG values were analyzed by surface electromyography analysis program (Surface EMG Analysis, Norupro Light Systems Co., Ltd.). The main frequency band of the EMG signal is 5-100 Hz. The potential is weak and susceptible to noise. Therefore, iEMG was filtered with a notch filter to remove the alternating current noise followed by a low-range cut-off filter (cut-off frequency 5 Hz) and by a high-range cut-off filter (cut-off frequency 100 Hz). The filtered waveform was divided by the length (time) of the phase, as defined above, to determine the average value. The surface EMG shows different potential at the electrode level among subjects, even if it is the same at the muscle or muscle fiber level, due to differences in the thickness of the subcutaneous fat or skin impedance. Therefore, it is necessary to perform normalization of EMG. However, there is no consensus on how to do this (Kizuka et al. 2006). In this study, we used the average of the measured values of left and right MLO in every subject before positioning as the data for the reference value (Equation 1). The reference value was the measured value of one minute before positioning divided by the time interval. The myogenic potential of each phase was determined by dividing the integral value of the potential (iEMG) of each phase by the length of the phase (seconds) (Equations 2 & 3).

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iEMG_{RP} = \int_{t_1}^{t_2} EMG(t) dt / (t_2 - t_1)
\]

\[
iEMG_{KP} = \int_{t_2}^{t_3} EMG(t) dt / (t_3 - t_2)
\]

An example of the EMG waveform of each phase is shown in Fig. 2. The average duration for the time of positioning was 55.5 seconds in KP and 10.9 seconds in PP. The average breast compression pressure was 122 N and the average thickness of the breast under compression was 3.44 cm.

Statistical analysis of EMG data

The measured value in RP was used as a reference and each value in KP and PP was compared (N = 15 subjects × 1 measured value = 15). A general statistics software SPSS ver.19.0 for Windows was used for statistical analysis and one-way analysis of variance was performed. In addition, analysis was performed after it was confirmed that the equality of variances was established by performing Levene’s test. In addition, Dunnett’s multiple comparison test was performed to compare RP with KP and PP. The level of significance was set at less than 0.05.

Analysis of VAS scores

VAS scores and body sites in each phase of RP, KP and PP were investigated and compared. This was performed during both the right and left positionings. This means that each subject was studied twice (N = 15 subjects × 2 trials (right and left positionings) = 30 measurements). The mean value of VAS and the sites of pain in each phase were determined.

Results

Muscle activity of each site during positioning for imaging

Muscle activities at the body sites of the imaging side were compared between the phases. Analysis of variance (ANOVA) showed the difference in iEMG from the reference value in all muscles (F = 5.423, P < 0.008 in biceps; F = 15.11, P < 0.000 in trapezius; F = 7.622, P < 0.001 in sternocleidomastoid; and F = 4.515, P < 0.017 in gastrocnemius). Multiple comparisons showed a significant difference between RP and KP, and RP and PP in all muscles. A comparison of mean values between phases is shown in Fig. 3. This shows that the muscle activities increased in all muscles of the imaging side during positioning for the MLO view. The muscle activities at the body sites on the opposite side to imaging were compared between the phases. ANOVA showed no difference in iEMG between phases in any of the muscles. Multiple comparisons

![Fig. 2. Waves of surface EMG with three phases for analysis.](image)
showed a significant difference between RP and PP in the biceps. A comparison of mean values between phases is shown in Fig. 4. This shows that muscle activity of the biceps on the side opposite to the imaging increases during the compression of the breast and positioning for the MLO view.

**Measurements and sites of subjective pain during MMG**

The mean and standard deviation of the VAS scores in these phases are shown in Table 1. This study was conducted on each of the 15 subjects during both right and left positionings. Therefore, the results are based on a total number of 30 trials. The mean VAS scores for KP and PP were 3.7 and 6.7, respectively. The overall mean VAS score for the two phases was 5.2, which was calculated averaging all VAS scores for KP and PP. The number of trials in which the subject gave the VAS score of 1.0 or more was 24 (80.0%) in KP and 29 (96.6%) in PP. Overall the breakdown shows 5.5 points in the shoulder, 4.0 points in the armpit, 5.0 points in the breastbone and rib, and 6.6 points in the breast in KP. All patients experienced moderate pain as indicated by scores of more than 4.0 points. According to area, the scores were 8.0 points in the cervix, 4.8 points in the waist, 3.7 points in the breastbone and rib, and 7.5
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points in the breast in PP. The site of pain in PP is most commonly the breast and the VAS score in the breast indicated severe pain. Fig. 5, together with Table 1, indicates body parts affected by the pain during MMG. The sites of pain in KP were: shoulder in 4 trials (13.3%), armpit in 8 trials (26.6%), breastbone and rib in 3 trials (10.0%) and breast in 5 trials (16.6%). These were consistent with the sites associated with arm elevation and with the compression plates during positioning. The sites of pain in PP were cervix in 1 trial (3.3%), waist in 2 trials (6.6%), breastbone and rib in 3 trials (10.0%) and breast in 23 trials (76.6%). Only infrequently was pain experienced in other sites besides the breast.

**Discussion**

**Impact on the muscle activity of each site during MMG**

In this study, muscle activity during the phase of holding the position during MMG and in the phase of breast compression was measured quantitatively using surface EMG. On the MMG imaging side, muscle activity was obviously increased compared to prior to imaging in the biceps, trapezius, sternocleidomastoid, and gastrocnemius muscles. On the other hand, on the side opposite the imaging, muscle activity was increased in the biceps, sternocleidomastoid and gastrocnemius muscles in both phases. This is believed to be associated with the positioning for the MLO view. For positioning for the MLO view, the technologist is instructed to "make the subject stand in front diagonally, raise the arm and bend toward the examined side, lean the upper body against the cassette holder so that the top corner of the cassette holder hits the axilla at the dorsal side of the pectoral muscle, place the breast on top of the cassette holder with the lateral side fully lifted to the front medially, bend the elbow and hang the arm down in back of the cassette holder, hold the handle with the hand lightly. If the other breast is in the way, have the subject press it aside by hand" (Henrich et al. 1999). Based on these instructions, keeping the upper arm elevated on the imaging side is associated with contraction of the biceps and trapezius muscles. In addition, since MLO is imaged from an oblique
direction of the breast, the neck is forced to bend to make it easier to insert the cassette holder at the time of imaging. In addition, the opposite breast is pressed out of the way so that it does not interfere with the imaging field, which supposedly increases the muscle activity of the biceps on the opposite side. This indicates that there is an impact not only on the breast directly but also on the surrounding muscle activities during MMG. Therefore, the imaging positioning affects the muscle activities from the start to the end of MMG.

**Association between muscle activity and pain during MMG**

In 80.0 to 96.6% of the trials, the subjects said that they felt pain as a result of the positioning during imaging. The affected sites were the armpit, breast, breastbone and rib, and shoulder. The overall mean VAS score was 5.2. The mean VAS scores at all sites were more than 4.0 points, indicating more than moderate pain. From the viewpoint of the intensity of the pain, subjective evaluation mostly reported pain in and around the breast in PP. In PP, breast compression was strongly felt and pressure resulted in direct pain. The physical burden is also present in the whole body at the same time, but subjects seemed to be unaware of the situation. These results indicate that subjective pain is also caused even in body sites other than the breast that is directly compressed during positioning for MMG. This was similar to the results reported by Sharp et al. (2003). From the relationship between the subjective markers and an increase in muscle activity, we found that the state of muscle activity also increased compared to the reference level at the sites where subjective pain occurs. Our results quantitatively showed that MMG positioning causes a physical burden to the subjects. In this study, sufficient data could not be obtained due to the measurement methods and the limited number of subjects. However, the increased muscle activity appears to be related to the pain. Further analysis is necessary to prove the relation between the increased muscle activity and pain during MMG.

**Proposal of care to reduce the physical burden during MMG**

In the present study, we were able to quantify the state of burden at the body sites other than the breast during MLO positioning which is a standard shooting method of MMG. Positioning and compression of the breast during MMG are prerequisites for shooting, and, therefore, they cannot be readily modified. However, it is considered possible to reduce the burden if the amount of muscle activity of the subjects can be reduced somehow. There is a potential to achieve a reduction of the burden of the whole body by promoting the awareness of body sites where the subject is not aware.

**Conclusion**

The muscle activity during MMG positioning was measured quantitatively using surface EMG. The measurement was performed in sternocleidomastoid, biceps, trapezius and gastrocnemius muscles in fifteen subjects. As a result, the differences in the amount of muscle activity were detected in all muscle groups at the side of shooting and biceps in the opposite side. The sites where the amount of muscle activity increased are almost identical to the sites of pain assessed with the subjective indicator, VAS. Thus, the subjects are under the substantial physical stress during MMG positioning. Once the stress state of the muscle activity at a given site during MMG positioning is quantified, the data are expected to be used effectively, such as in the care to reduce pain for the subjects. For that, further quantitative analysis with addition of the background of the subjects and the number of samples is necessary.

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**Conflict of Interest**

All authors have no conflict of interest to declare.

**References**


