XXI IMEKO World Congress "Measurement in Research and Industry"
August 30 – September 4, 2015, Prague, Czech Republic

MEASUREMENT OF PUPIL SIZE DURING MAMMOGRAPHY

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Abstract **–** Many women feel the physical burden during mammography as pain. We examined the pain-related pupil dilation response during mammography. The pupil sizes of 24 women were measured during mammography excluding x-ray irradiation. Their mean pupil diameter was 2.9 mm in relaxation phase before mammography, while it was 3.2 mm in a few seconds after breast compression. The difference in pupil diameter between the relaxation and pressure phases was statistically significant.

Keywords: mammography, pupil dilation response, pain assessment, objective indicator

1. INTRODUCTION

Mammography is the most effective method available for the early diagnosis of breast cancer [1] and regular screening can significantly reduce mortality [2]. However, it is unfortunate that many women experience pain during mammography [3-9] because the breast is compressed by parallel plates to make the breast tissue as even and thin as possible. In addition to the breast compression, the pain is due to the positioning required, such as twisting the neck and raising the arm (Fig. 1).

Appropriate techniques for radiography and management of the mammography device to obtain accurate images have been established. This has made it possible to obtain good radiographic images of the breast [10-13]. However, studies are lacking on objective methods to measure the physical burden on women and the alleviation of pain during mammography.

Several subjective assessment scales such as visual analogue scale (VAS) [14,15] and McGill pain questionnaire (MPQ) [16] were used to predict pain during mammography [6,7]. The MPQ could be considered as the most famous pain assessment tool, but the process is a little complicated to obtain reliable MPQ scores, while the VAS is perhaps the most widely used instrument for the measurement of pain intensity because it is a simple, robust, sensitive, and reproducible instrument. Furthermore, whereas the VAS takes only a few minutes, the MPQ requires about 15 minutes.

As to the alleviation of pain during mammography, a few investigators have reported on the usefulness of radiolucent cushions [17,18]. However, their use is debatable because of the high cost since these cushions are single-use. Patient-controlled compression was tested as a method to alleviate pain [19]. With this method, one of the breasts was compressed by a radiographer and the other was compressed by the participant. In 71% of the participants, self-compression resulted in significantly less pain than compression by a radiographer without a difference in the adequacy of the image quality and compression of the breast. It has been also reported that the humorous stimuli would relieve pain during mammography [20]. According to the report, the pain experienced during conventional mammography without the funny video was significantly greater than the pain experienced during the same mammography but with the funny video. There are limited options currently available for alleviating pain related to mammography and further research will be needed to address this problem.

Recently, muscle activities [21,22] and sympathetic nervous activities [23] have been measured to estimate physical burden and psychological stress associated with mammography, respectively. These were objective assessment studies for quantification of pain or stress during mammography. The valuable objective assessment tools for quantifying the pain intensity should be further investigated. More research is therefore required using a validated pain measurement to establish the extent of pain and to establish the effect of this on future compliance [9].

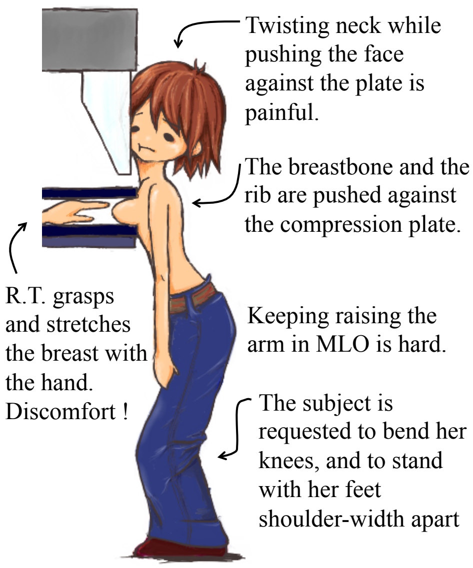

Fig. 1. Mammography positioning with physical and psychological burden in addition to the breast compression.

In the meantime, the pupil dilates markedly in response to increasing noxious stimulation in humans [24]. It has been reported that the pupil dilation response increased significantly with increasing intensity of pain stimulus [25]. These investigations suggest that the extent of pupil dilation response may provide a useful objective indicator for estimating pain quantitatively.

We therefore examined the pain-related pupil dilation response during mammography.

Fig. 2. The Eye Mark Recorder used to measure pupil sizes (left: head unit with camera, right: control unit).

Fig. 3. A screenshot captured from video output of the Eye Mark Recorder EMR-9 (upper left: view image, bottom right: eye image, upper right: binary image with pupil region automatically detected from eye image, bottom left: blank).

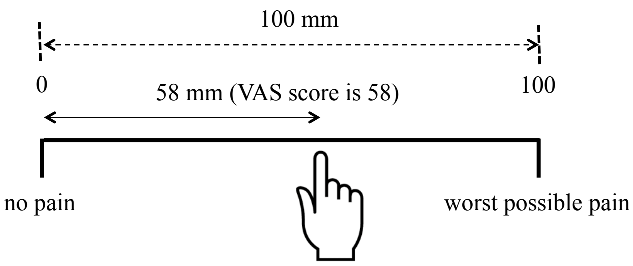

Fig. 4. Visual analogue scale for subjective pain assessment.

2. MATERIALS AND METHODS

Volunteers were solicited for this study through poster advertisements. Twenty-four healthy women contacted us. Their mean age ± standard deviation (SD) was 23.6 ± 6.4 years, height was 159.5 ± 6.6 cm, weight was 52.2 ± 5.6 kg. Two of the 24 women had experienced mammography, and the remaining 22 had not. The participants were given explanation on the study objectives, methods, and safety, and their informed consent was obtained. This study was approved by the Research Ethics Committee of the Niigata University School of Medicine.

Observation in the study took place beginning at the end of positioning of the right breast, including compression, for mediolateral oblique (MLO) imaging but excluding x-ray irradiation. During the sham mammography, the Eye Mark Recorder (EMR-9; nac Image Technology Inc., Tokyo, Japan) (Fig. 2) that is a device for measuring a subject's point of visual focus and pupil diameter was used to measure pupil sizes of participants. Figure 3 shows a screenshot obtained from video output of the Eye Mark Recorder.

The pupil size was measured during the following 4 phases in mammography. 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). The interval between breast fixing and the end of imaging, which was actually sham because the participants were not irradiated by x-ray, was defined as the Pressure Phase (PP). The PP was further divided into two sections. The first half and later half were defined as PP_F and PP_L, respectively. The phase after the examination was defined as the After Phase (AP).

The subjective intensity of pain during mammography was also assessed using the VAS. The VAS consisted of a horizontal line of 100 mm with scoring in increments of 1 mm from "no pain at all" at the leftmost position (0 points) to "the worst pain you have ever felt" on the rightmost position (100 points). Figure 4 shows a diagram of the VAS. The participants were asked to point with their finger to the level of pain they were feeling during whole mammography.

3. RESULTS AND DISCUSSION

Figure 5 shows a graph of mean pupil diameter obtained from all participants. Means and standard deviations (SDs) of measured pupil diameter in each phase were shown in Table 1. The pupil sizes of RP, KP, PP_F, PP_L and AP were 2.93 ± 0.79 mm, 2.94 ± 0.92 mm, 3.15 ± 1.36 mm, 2.92 ± 1.26 mm and 2.82 ± 0.85 mm, respectively. Figure 6 shows sequential binary images that represent pupil regions of a subject from RP to AP.

The mean pupil size of PP_F was obviously larger than that of other phases. The differences in pupil diameter between the PP_F and other phases were statistically significant ($p < 0.05$). Compressing breast usually gives strongest intensity of pain to woman undergoing

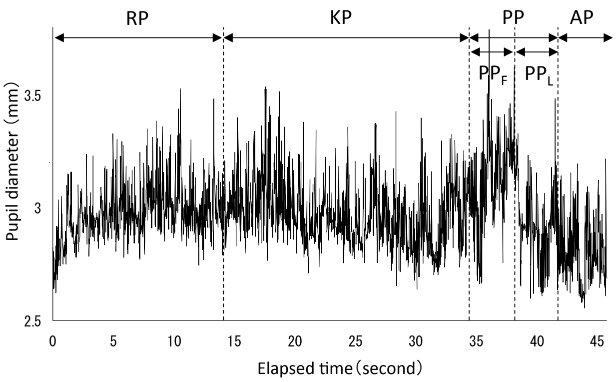

Fig. 5. A graph of mean pupil diameter obtained from all participants (RP: relaxation phase, KP: keep phase, PP; pressure phase, PP_F: first half of PP, PP_L: later half of PP, AP: after phase).

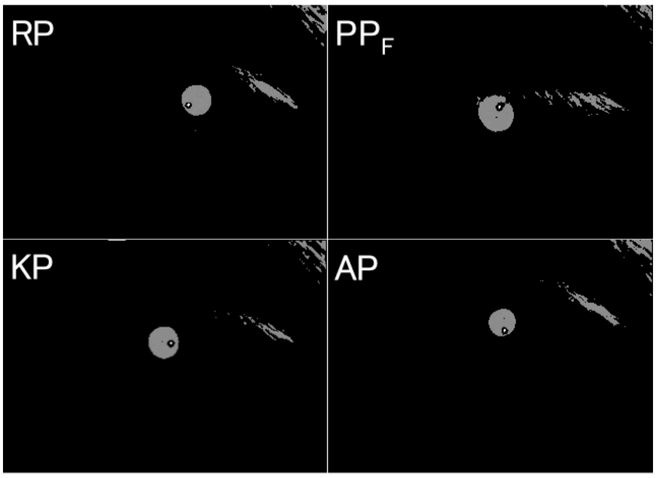

Fig. 6. Sequential binary images that represented pupil regions of a subject. The pupil region of PP_F looks larger than that of other phases.

Table 1. Mean and standard deviation (SD) of measured pupil diameter (mm) in each phase during mammography.

	RP	KP	PP_F	PP_L	AP
Mean	2.93	2.94	3.15	2.92	2.82
SD	0.79	0.92	1.36	1.26	0.85

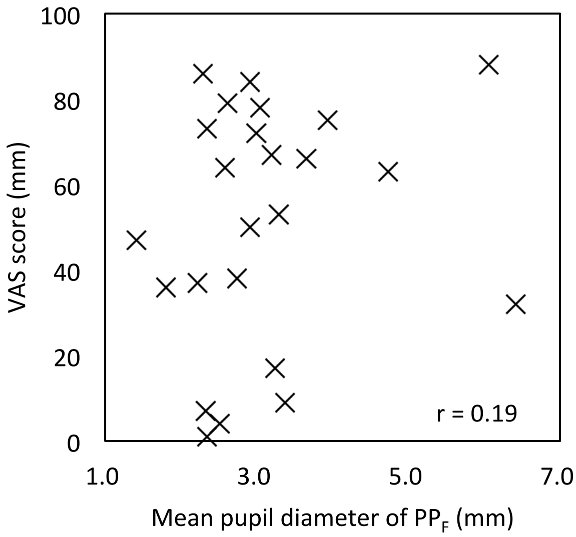

Fig. 7. The relationship between VAS scores and mean pupil diameters of PP_F.

mammography. Pupil dilation at PP_F must be related with this matter. We found out the pain-related pupil dilation response during mammography. This finding suggests that we may be able to assess objectively the degree of pain associated with mammography.

Figure 7 shows the relationship between VAS scores and mean pupil diameters of PP_F. The correlation coefficient between the VAS scores and the pupil diameters was 0.19. This result means that there is no linear correlation or a weak linear correlation between the two variables. Although the subjective and objective data do not always match, we were expecting a strong positive correlation between the VAS scores and the pupil diameters. Since one reason of the inconsistency may be due to the small number of participants, the recruitment of subjects may be necessary to our future works. The relation between the intensity of pain and the degree of pupil dilation should be further investigated.

4. CONCLUSIONS

The pupil sizes of 24 women undergoing mammography excluding x-ray irradiation were measured to investigate the pain-related pupil dilation response during mammography. The pupil size in a few seconds after breast compression was obviously larger than that of relaxation phase before mammography. This result may give us to quantitatively estimate the degree of pain associated with mammography in the near future. The visual analogue scale (VAS) was also used to assess subjective intensity of pain during mammography. There was no correlation between the obtained VAS scores and pupil sizes, although we were expecting a strong positive correlation. We would need to conduct additional investigations into the relation between the intensity of pain and the degree of pupil dilation.

ACKNOWLEDGMENTS

The authors thank Ms. Kanae Nagai for assisting with experiments and data analysis. This study was supported by JSPS KAKENHI [Grant-in- Aid for Scientific Research (C)] (No. 26463372, 2014-2017).

REFERENCES

[1] B.H. Drukker, "Breast disease: a primer on diagnosis and management", *Int J Fertil Womens Med*, vol.42, no.5, pp.278-287, Sept. 1997.

[2] K. Kerlikowske, D. Grady, S.M. Rubin, C. Sandrock, V.L. Ernster, "Efficacy of screening mammography. A meta-analysis", *JAMA*, vol.273, no.2, pp.149-154, Jan. 1995.

[3] V.P. Jackson, A.M. Lex, D.J. Smith, "Patient discomfort during screen-film mammography", *Radiology*, vol.168, no.2, pp.421-423, Aug. 1988.

[4] A.R. Aro, P. Absetz-Ylostalo, T. Eerola, M. Pamilo, J. Lonnqvist, "Pain and discomfort during mammography", *European Journal of Cancer*, vol.32, no.10, pp.1674-1679, Sept. 1996.

[5] M.E. Keemers-Gels, R.P. Groenendijk, J.H. Van Den Heuvel, C. Boetes, P.G. Peer, T.H. Wobbes, "Pain experienced by women attending breast cancer screening", *Breast Cancer Research and Treatment*, vol.60, no.3, pp.235-240, Apr. 2000.

[6] B. Hafslund, "Mammography and the experience of pain and anxiety", *Radiography*, vol.6, no.4, pp.268-272, Nov. 2000.

[7] P.C. Sharp, R. Michielutte, R. Freimanis, L. Cunningham, J. Spangler, V. Burnette, "Reported pain following mammography screening", *Arch Intern Med*, vol.163, no. 7, pp.833-836, Apr.2003.

[8] A. Asghari, M.K. Nicholas, "Pain during mammography: the role of coping strategies", *Pain*, vol.108, no.1-2, pp.170-179, Mar. 2004.

[9] B. Davey, "Pain during mammography: possible risk factors and ways to alleviate pain", *Radiography*, vol.13, no.3, pp.229-234, Aug. 2007.

[10] A.G. Haus, "Historical technical developments in mammography", *Technol Cancer Res Treat*, vol.1, no.2, pp.119-126, Apr 2002.

[11] K.H. Ng, N. Jamal, L. DeWerd L., "Global quality control perspective for the physical and technical aspects of screen-film mammography--image quality and radiation dose", *Radiat Prot Dosimetry*, vol.121, no.4, pp.445-451, May 2006.

[12] K.J. Robson, "Advances in mammographic imaging", *Br J Radiol*, vol.83, no.988, pp.273-275, Apr 2010.

[13] T. Yamada, "Current status and issues of screening digital mammography in Japan", *Breast Cancer*, vol.17, no.3, pp.163-168, Jul 2010.

[14] K.D. Keele, "The pain chart", *Lancet*, vol.252, no.6514, pp.6-8, July 1948.

[15] D.C. Turk, R. Melzack, *Handbook of Pain Assessment*. 2nd Edition. The Guilford Press, New York, 2001.

[16] R. Merzack, "The McGill pain questionnaire: major properties and scoring methods", *Pain*, vol.1, no.3, pp.277-299, Sep 1975.

[17] L. Tabar, G.S. Lebovic, G.D. Hermann, C.S. Kaufman, C. Alexander, J. Sayre, "Clinical assessment of a radiolucent cushion for mammography", *Acta Radiologica*, vol.45, no.2, pp.154-158, Apr 2004.

[18] L. Markle, S. Roux, J.W. Sayre, "Reduction of discomfort during mammography utilizing a radiolucent cushioning pad", *Breast Journal*, vol.10, no.4, pp.345-349, Jul-Aug 2004.

[19] P.J. Kornguth, B.K. Rimer, M.R. Conaway, D.C. Sullivan, K.E. Catoe, A.L. Stout, J.S. Brackett, "Impact of patient-controlled compression on the mammography experience", *Radiology*, vol.186, no.1, pp.99-102, Jan 1993.

[20] Y. Lee, M. Uchiyama, "The effect of humorous stimuli on alleviating pain during mammography: a preliminary study", *Health*, vol.7, no.6, pp.659-664, June. 2015.

[21] M. Uchiyama, Y. Lee, M. Sadakata, M. Sayama, D.Y. Tsai, "Measurement of muscle activities for evaluating physical burden and pain during mammography positioning", *Tohoku J Exp Med*, vol.228, no.1, pp.53-58, Sep. 2002.

[22] M. Uchiyama, Y. Lee, M. Sadakata, D.Y. Tsai, M. Sayama, "Quantification of the pain and physical burden experienced during positioning for craniocaudal imaging in mammography, evaluated by measurement of muscle activity", *Health*, vol.7, no.1, pp.23-34, Jan. 2015.

[23] M. Uchiyama, Y. Lee, M. Sadakata, K. Kazama, Y. Minagawa, M. Tsurumaki, "Effects of mammography positioning on the autonomic nervous function", *Health*, vol.5, no.8, pp.1335-1341, Aug. 2013.

[24] S. Oka, C.R. Chapman, B. Kim, I. Nakajima, O. Shimizu, Y. Oi, "Pupil dilation response to noxious stimulation: Effect of varying nitrous oxide concentration", *Clin Neurophysiol*, vol.118, no.9, pp.2016-2024, Sep. 2007.

[25] C.R. Chapman, S. Oka, D.H. Bradshaw, R.C. Jacobson, G.W. Donaldson, "Phasic pupil dilation response to noxious stimulation in normal volunteers: relationship to brain evoked potentials and pain report", *Psychophysiology*, vol.36, no.1, pp.44-52, Jan. 1999.