Fatty induration that is associated with necrosis remains a common complication in breast reconstructions with autologous flaps after mastectomy. Fat induration can cause deep tissue infection, pain, distress, and anxiety. However, the diagnosis for this problem has not been objectively defined. In the current article, we will share our experience of using ultrasound shear-wave elastography with 14 patients who had clinical fat induration after breast reconstruction with a deep inferior epigastric perforator (DIEP) flap. The experience suggested that shear wave elastography may be a noninvasive tool to assess alterations of tissue stiffness in a reproducible fashion after breast reconstruction with DIEP flaps. Complications, such as fat necrosis and fatty induration, may occur as a result of unstable blood flow to the flap. Thereby, objective assessments of stiffness might make a major contribution to the understanding of hemodynamics of the DIEP flap after transplantation. (Plast Reconstr Surg Glob Open 2015;3:e518; doi: 10.1097/GOX.0000000000000493; Published online 22 September 2015.)

Yoshihiro Sowa, PhD, MD
Toshiaki Numajiri, PhD, MD
Kenichi Nishino, PhD, MD

Summary: Fat induration is associated with necrosis and remains a common complication in breast reconstructions with autologous flaps after mastectomy. Fat induration can cause deep tissue infection, pain, distress, and anxiety. However, the diagnosis for this problem has not been objectively defined. In the current article, we will share our experience of using ultrasound shear-wave elastography with 14 patients who had clinical fat induration after breast reconstruction with a deep inferior epigastric perforator (DIEP) flap. The experience suggested that shear wave elastography may be a noninvasive tool to assess alterations of tissue stiffness in a reproducible fashion after breast reconstruction with DIEP flaps. Complications, such as fat necrosis and fatty induration, may occur as a result of unstable blood flow to the flap. Thereby, objective assessments of stiffness might make a major contribution to the understanding of hemodynamics of the DIEP flap after transplantation. (Plast Reconstr Surg Glob Open 2015;3:e518; doi: 10.1097/GOX.0000000000000493; Published online 22 September 2015.)

Ultrasound elastography, especially shear-wave elastography (SWE), is a relatively new technology that entered the clinic in the last decade. SWE is an imaging technique that quantifies tissue stiffness by measuring the speed of shear waves in the tissue. The speed can either be directly used as an indicator of stiffness or converted to Young’s modulus. A low speed corresponds to a soft tissue, whereas a high speed indicates a stiff tissue. This system displays real-time, color-coded elastograms of either the shear wave speed (m/sec) or elastic modulus (kPa) in a one-dimensional map, and quantitative measurements can be obtained within a region of interest (Fig.1). Since its introduction, ultrasound elastography has enabled the evaluation of many different types of organs, including the breast, liver, prostate, thyroid glands, blood vessels, salivary glands, musculoskeletal structures, and cervical lymph nodes. The device used in this study was a GE Healthcare LOGIQ E9 ultrasound scanner with real-time SWE and a 9L linear (4–9 MHz) probe (GE Healthcare, Amersham Place, Little Chalfont, Buckinghamshire, UK). This device can quantify tissue stiffness by

Disclosure: The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.
measuring the speed of shear waves in tissues and can display the data on an absolute scale. Our experience with 14 fat induration cases suggested that SWE may be a noninvasive tool to assess alterations of tissue stiffness in a reproducible fashion after breast reconstruction with DIEP flaps. Our preliminary data indicated that fatty induration was often localized in the distal region in Hartrampf zone II (8 cases, 57.1%), which is consistent with the previous angiosome concept in the DIEP flap method (Fig. 2).4 Degree of stiffness measured by SWE had a consistent correlation with that by palpation.

Following are 2 representative cases. A 53-year-old patient (case no 7), who underwent left breast reconstruction with an adipose DIEP flap based on a single, large, and contralateral medial row perforating vessel, had a sustained fatty induration for 6 months (Fig. 3A) in the superior medial area of the breast. SWE was used to investigate fatty stiffness quantitatively and showed increased stiffness (mean, 22.3 kPa) when compared with lateral area (mean, 6.6 kPa) (Fig. 3B). A 62-year-old patient (case no 8), who underwent left breast reconstruction with a cutaneous-adipose DIEP flap based on a single, small, and contralateral medial row perforating vessel 10 months ago, complained of breast mass with pain and stiffness in the medial region (Fig. 4A). B-mode imaging showed that the breast mass was likely not postoperative edema or hematoma. SWE showed a significantly higher stiffness (mean, 107.4 kPa) when compared with the lateral area (mean, 13.9 kPa) (Fig 4B). These findings indicated that the breast mass was associated with fat necrosis.

Ultrasound elastography techniques can be broadly divided into 2 groups: strain elastography and shear wave-based elastography. We strongly recommend this technique in combination with either B-mode image or SWE for detection of tissue deformation or stiffness. The strain ratio was calculated by dividing the mean strain of the reference normal tissue by the mean strain within the breast lesion. However, there is no consistency in selecting the reference normal tissue. Unlike strain elastography, SWE quantifies tissue stiffness on an absolute scale. Fat induration or necrosis is a well-recognized complication after autologous reconstruction that can give an unfavorable result. Care should be taken to thoroughly evaluate these firm areas, and if any concern exists regarding the diagnosis, SWE is rec-
commended to successfully detect suspected areas of fatty induration while maintaining a favorable breast contour. The early recognition and precise diagnosis of fatty induration by SWE might enable good management, unlike surgical excision or liposuction accompanied with contour deformities. For instance, a simplified technique called “needle aeration” is effective for managing early recognized hard nodules of fat necrosis in a population of patients who had undergone previous autologous breast reconstruction.5

Stiffness of adipose tissue after breast reconstruction with autologous flaps is considered to be strongly associated with the hemodynamics of the
DIEP flap. Complications, such as fat induratin or necrosis, may occur as a result of unstable blood flow to the flap.\textsuperscript{6,7} Thereby, objective assessments of stiffness might make a major contribution to the understanding of hemodynamics of the DIEP flap after transplantation.

**CONCLUSIONS**

Our preliminary experience suggests that SWE may be useful in facilitating surgical follow-up and acceptable in clinical practice. Although ultrasonography is a technique that can be widely used in daily practice and has defined the size and location of tissue deformations, there are no reports that measure stiffness using ultrasound elastography. For the future, the optimal cut-off values for either significant fat induration or necrosis after breast reconstruction using the autologous flap procedure should be determined to define the diagnostic criteria and provide further reliability.

**ACKNOWLEDGMENTS**

All experimental procedures and protocols for animals conformed to the National Institutes of Health Guide for the Care and Use of Laboratory Animals and were approved by the Committee for Animal Research of Kyoto Prefectural University of Medicine.

**REFERENCES**

1. Casey WJ III, Rebecca AM, Silverman A, et al. Etiology of breast masses after autologous breast reconstruction. *Ann Surg Oncol*. 2013;20:607–614.
2. Kroll SS. Fat necrosis in free transverse rectus abdominis myocutaneous and deep inferior epigastric perforator flaps. *Plast Reconstr Surg*. 2000;106:576–583.
3. Bercoff J, Tanter M, Fink M. Supersonic shear imaging: a new technique for soft tissue elasticity mapping. *IEEE Trans Ultrason FerroelectrFreq Control* 2004;51:396–409.
4. Choi YJ, Lee JH, Baek JH. Ultrasound elastography for evaluation of cervical lymph nodes. *Ultrasonography* 2015;34:157–164.
5. Jandali S, Bucky LP. A simplified technique for the management of fat necrosis in autologous breast reconstruction. *J Plast Reconstr Aesthet Surg*. 2011;64:831–833.
6. Bailey SH, Saint-Cyr M, Wong C, et al. The single dominant medial row perforator DIEP flap in breast reconstruction: three-dimensional perforasome and clinical results. *Plast Reconstr Surg*. 2010; 126:739–751.
7. Figus A, Moshebi A, Ramakrishnan V. Microcirculation in DIEP flaps: a study of the haemodynamics using laser Doppler flowmetry and lightguide reflectance spectrophotometry. *J Plast Reconstr Aesthet Surg*. 2006; 59:604–612.

---

*Yoshihiro Sowa, PhD, MD*
Department of Plastic and Reconstructive Surgery
Kyoto Prefectural University of Medicine
Graduate School of Medical Sciences
Kawaramachi-Hirokoi Kajii-cho 465
Kamigyo-ku, Kyoto 602–8566, Japan
E-mail: sowawan@kpu-m.ac.jp