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The Shear Wave Velocity on Elastography Correlates with the Clinical Symptoms and Histopathological Features of Keloids

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Background: Keloids present as red, painful lesions causing serious functional and cosmetic problems; however, there is no consensus regarding tools for objectively evaluating keloids. To demonstrate the utility of shear wave elastography in keloids, we investigated the correlations between clinical symptoms, ultrasound shear wave velocity, and histopathological findings.
Methods: Three patients with keloids containing both red hypertrophic and mature areas were evaluated using the shear wave velocity and histopathological findings.
Results: The results indicate that the shear wave velocity is high in active hypertrophic areas and low in mature areas. The areas with high elastography values exhibited numerous fibrillar collagenous matrices forming a whorled pattern with hyalinized tissue on hematoxylin-eosin staining corresponding with metachromasia on toluidine blue staining. In the mature area, the collagen fibers were oriented parallel to each other without metachromasia.
Conclusions: Shear wave elastography provides quantitative estimates of tissue stiffness that correlate with the clinical symptoms and histopathological findings of the keloid lesions and can be used to assess the activity of keloids. *(Plast Reconstr Surg Glob Open 2015;3:e464; doi: 10.1097/GOX.0000000000000445; Published online 21 July 2015.)*

Keloids occur in predisposed individuals spontaneously or following trauma, inflammation, surgery, or burns.[1] Despite being benign dermal tumors, keloids present as raised, red, itchy, painful lesions causing serious functional and cosmetic problems.

Multiple treatment modalities are used to treat keloids; however, due to high recurrence and unknown resolution rates, there is no decisive therapy.[2] To improve therapeutic results, it is important to select appropriate treatments based on accurate assessments performed throughout the disease course. However, there is also no consensus regarding tools for objectively evaluating the characteristics of cutaneous scarring.[3] We previously reported using ultrasound strain elastography to assess keloids.[4] In this report, we demonstrate that ultrasound elastography can be used to effectively determine the stiffness of keloids, that is, active hypertrophic keloids are stiffer than mature flattened keloids.

To demonstrate the accuracy of ultrasound elastography, we investigated the correlations between clinical symptoms, ultrasound shear wave velocity, and histopathological findings.

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MATERIALS AND METHODS

An Acuson S3000 ultrasound machine with Acoustic Radiation Force Impulse (ARFI) Virtual Touch IQ shear wave elastography and a 9L4 linear probe (9 MHz) (Siemens Medical Solutions, Mountain

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View, Calif.) was applied. This device emits short-duration acoustic pulses that induce tissue compression, which subsequently generates shear waves that propagate into the tissue perpendicularly to the direction of the acoustic pulse. The shear waves are then tracked using the ultrasound correlation-based method in a small region of interest (ROI), which the examiner can freely locate.[5] The shear wave velocity increases as the tissue becomes stiffer.

We evaluated 3 patients with keloids containing both red hypertrophic and mature areas. All patients were scheduled for keloid resection. After performing shear wave elastography, the keloids were resected, and a histopathological analysis, including hematoxylin-eosin (HE) staining and toluidine blue (TB) staining at a pH of 2.5, was conducted.

RESULTS

Case 1

A 76-year-old woman exhibited an abdominal keloid extending beyond the initial scar after gynecological

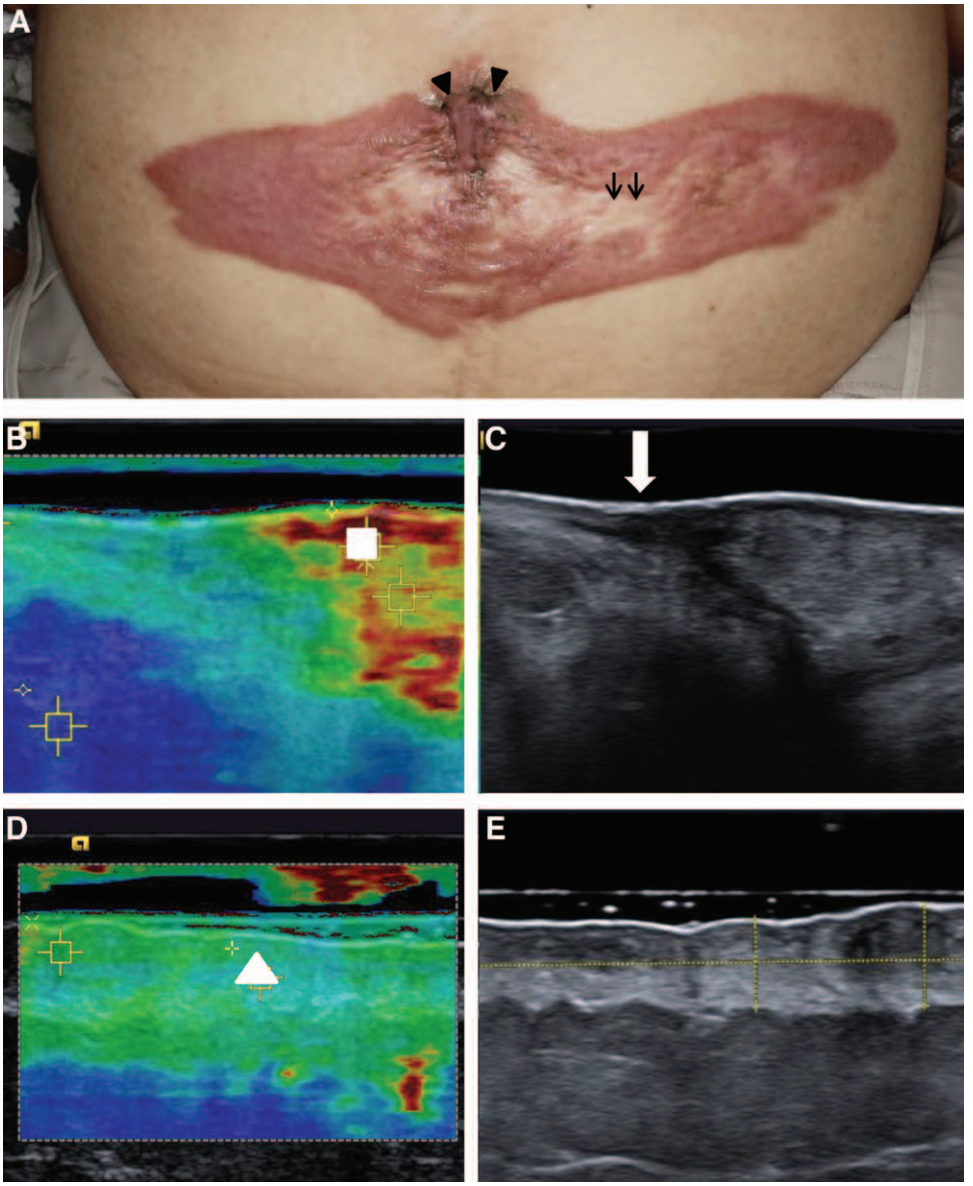

Fig. 1. Case 1. Abdominal keloid in a 76-year-old woman (A). The keloid contained a hypertrophic area (arrowhead) and mature area (arrow). Ultrasound elastography and B-mode image of the hypertrophic area (B). The white arrow shows the boundary between the normal skin and the keloid. The velocity on elastography measured in the white square in the hypertrophic area was v = 7.09 m/s. Image of the mature lesion (C). The velocity on elastography measured in the white triangle was v = 3.12 m/s.

surgery. The keloid contained 2 areas: a hypertrophic area located around the scar, with redness, pain, and itching, and a central mature area (Fig. 1). We measured the shear wave velocity in the 2 areas using elastography [v = 8.06 m/s in the hypertrophic area (Fig. 1) and v = 2.49 m/s in the mature area (Fig. 1)]. The hypertrophic area demonstrated numerous fibrillar collagenous matrices forming a whorled pattern with hyalinized tissue on HE staining (Fig. 2A) and metachromasia on TB staining, indicating glycosaminoglycan (GAG) accumulation (Fig. 2B). By contrast, the collagen fibers in the mature area were oriented parallel to each other on HE staining (Fig. 2C) without metachromasia on TB staining (Fig. 2D).

Cases 2 and 3

Case 2 involved a 42-year-old woman with a keloid originating from an unknown origin on the lateral surface of the right arm (Fig. 3A). Both edges of the lesion were hypertrophic, whereas the middle tended to be mature. The shear wave velocity was v = 7.09 m/s and v = 3.12 m/s in the hypertrophic and mature areas, respectively. Case 3 involved a 53-year-old man with a keloid of unknown cause in the right scapular region (Fig. 4A). The shear wave velocity was v = 5.62 m/s in the hypertrophic area and v = 3.34 in the mature area. The histopathological findings in both cases showed many proliferating cells with abnormal collagen (Figs. 3B, 4B) and GAG (Figs. 3C, 4C) accumulation.

DISCUSSION

Our data indicate that the shear wave velocity is high in active hypertrophic areas and low in mature areas. The areas with high elastography values exhibited numerous fibrillar collagenous matrices forming a whorled pattern with hyalinized tissue on HE staining corresponding with metachromasia on TB staining. These data suggest that the shear wave velocity is consistent with the activity of keloids assessed based on clinical and histopathological findings.

ARFI Virtual Touch IQ shear wave elastography provides objective, noninvasive information regarding the stiffness of organs, including the liver, breast, and thyroid,[5–8] and exhibits good diagnostic accuracy for liver fibrosis staging.[6] In breast and thyroid masses, ARFI indicates the cutoff value for benign and malignant tumors.[7,8]

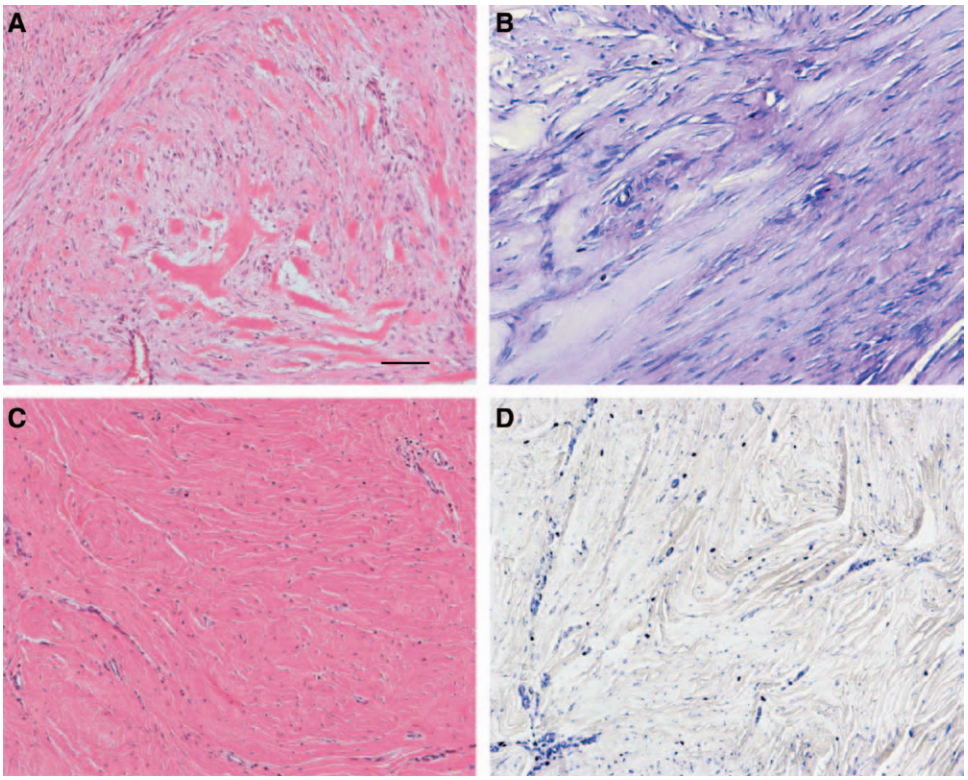

Fig. 2. HE staining of the hypertrophic area revealed numerous fibrillar collagenous matrices forming a whorled pattern with hyalinized tissue (A) and the presence of massive amounts of GAGs in the matrices, as evidenced by the detection of metachromasia on TB staining (B). In the mature area, the collagen fibers were comparatively oriented parallel to each other on HE staining (C), with no metachromatic findings on TB staining (D). Bar = 100 μm.

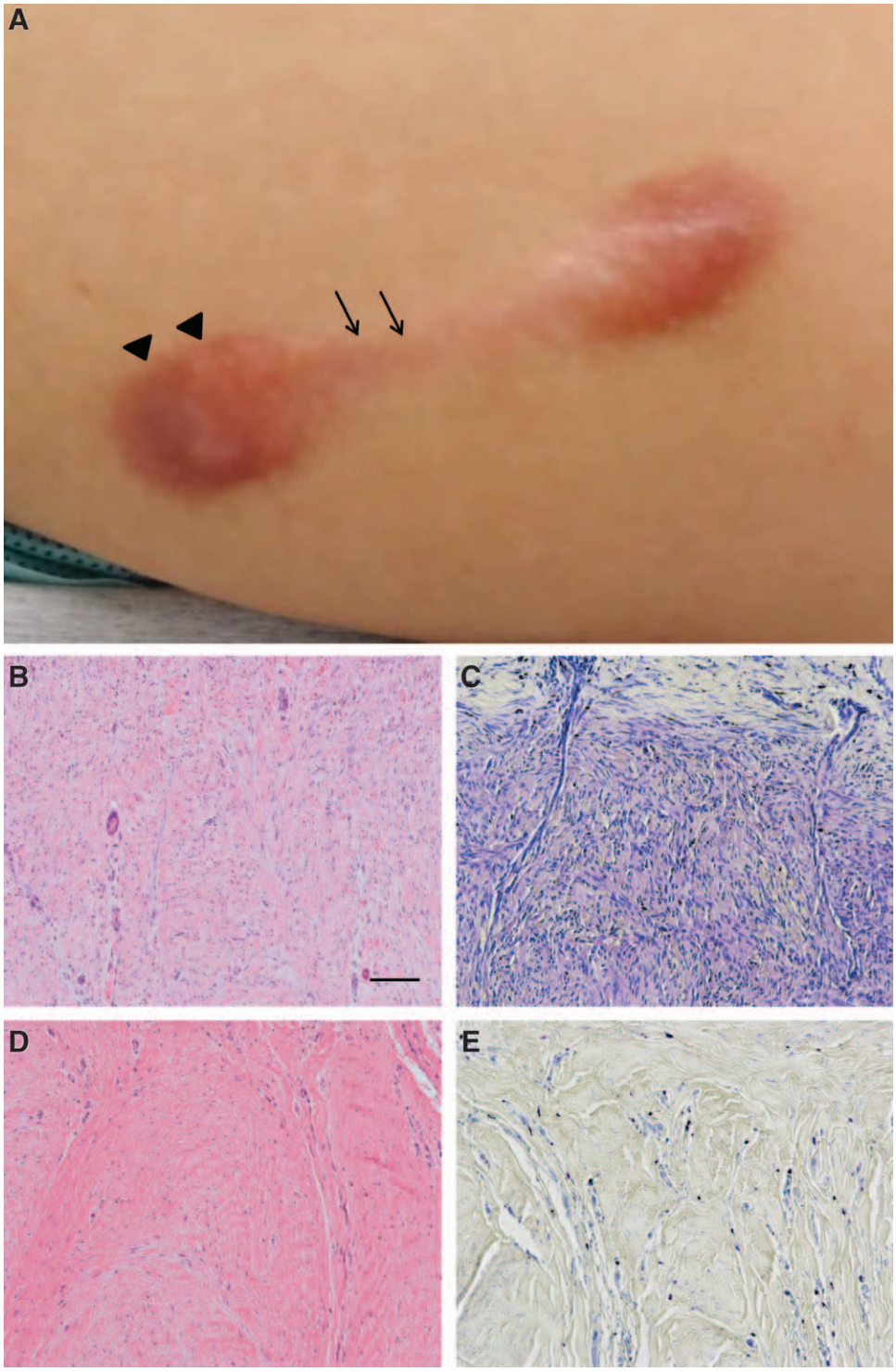

Fig. 3. Case 2. A keloid on the lateral surface of the right arm (A). HE staining of the hypertrophic area revealed many proliferating cells with the abnormal accumulation of collagen (B) and GAGs on TB staining (C). The mature area showed fewer sites of abnormal collagen (D) and GAGs (E). Bar = 100 μm.

Ultrasonography demonstrates good basic accuracy and reliability in skin scar management[3,9,10]; however, the efficacy of assessing stiffness using ultrasound elastography has not been established. We previously demonstrated the effectiveness of ultrasound elastography for evaluating keloids.[4] In

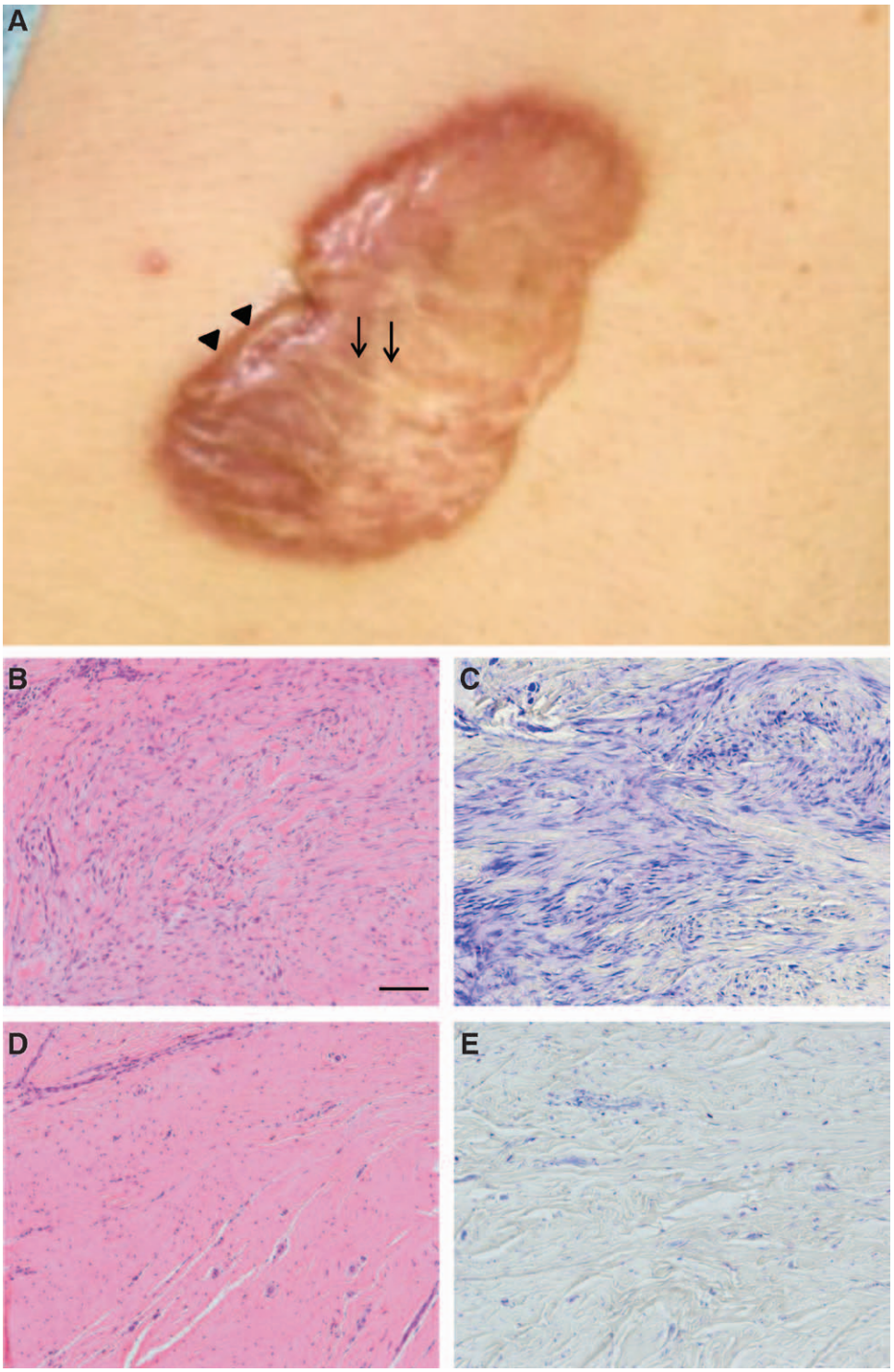

Fig. 4. Case 3. A keloid in the right scapular region (A). The hypertrophic area exhibited abnormal collagen on HE staining (B) and GAGs on TB staining (C). The mature area contained fewer sites of abnormal collagen (D) and GAGs (E). Bar = 100 μm.

this study, we used strain elastography to calculate the extent of tissue deformation or strain induced by stress applied with slight free-hand compression and found that this method provides qualitative measurements of stiffness expressed as a ratio to that observed in a control region. Shear wave elastography provides quantitative estimates of tissue stiffness based on shear wave propagation and is not depen-

dent on the examiner.[7] This modality is thus useful for quantitatively evaluating keloid stiffness.

Keloids have been shown to contain disorganized collagen with bundles that are thicker and hyalinized.[2,11] We previously demonstrated that GAGs are abundant in the keloid matrix.[12,13] In this study, the pathological findings of the hypertrophic areas correlated with high values on shear wave elastography.

CONCLUSIONS

In conclusion, shear wave elastography provides quantitative estimates of tissue stiffness that correlate with the clinical symptoms and histopathological findings of the keloid lesions. Although further investigations are required before this modality can be applied clinically as a standard assessment tool, shear wave elastography can be used to assess the activity of keloids.

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