Elastography of Healthy and Reconstructed Cleft Lip.

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Abstract
We have undertaken a study to assess the potentials of ultrasound elastography to evaluate cleft lip reconstruction. Rf-data is acquired with a linear array transducer (7-11 MHz) and a Philips Sonos 7500 equipment from patients and normal individuals during contraction of the lips. Cross-correlation analysis was performed to assess the deformation of the tissue along the ultrasound beams.

In normal individuals, the muscle region is expanding due to the contraction of the muscle (contraction direction is perpendicular to the ultrasound beams). The surrounding tissue is compressed due to the muscle contraction. In patients with reconstructed cleft lip, the expanding muscle is interrupted in the region where scar tissue is supposed to be present. In conventional ultrasound the scar region is not always visible in the muscle tissue.

Elastography of reconstructed cleft lip visualizes the effects of surgery but further research is needed to identify the clinical usefulness of this technique.

Introduction
One out of 500 to 1000 babies are born with a facial cleft [1]. Cleft lip, with or without cleft palate, is the most common of these facial clefts. Reconstruction of the upper lip and the restoration of the continuity of circular muscle in the lip (muscle orbicularis oris) is an important step in the treatment of these children. However, a surgical intervention leads inevitably to scar formation. The amount of scar tissue and its position both have functional and esthetic consequences [2]. The esthetic outcome of an intervention may be visually judged, but it remains unclear whether the continuity and functionality of the muscle have been restored. For this reason a simple, convenient and cost effective method to establish the quality of the reconstruction is wanted.

Ultrasound imaging enables the visualization of different tissues in the healthy and reconstructed upper lip [3]. The superficial epidermal layer yields a clear thin echo border and the connective tissue of the lip returns relatively bright echo values, whereas the deeper laying muscles are characterized by low intensity echo levels. However the characterization of the scar region and functionality of the muscle remains limited [4], since the analysis is based on conventional echograms. In this study, elastography is used to identify the presence and the amount of scar tissue in reconstructed cleft lips, as well as to investigate the functionality of the muscle.

Materials
Elastograms were made of patients with a reconstructed cleft lip (n=2) and of normal individuals (n=2).
Methods
Rf-data were acquired using a Philips SONOS 7500 live 3D ultrasound system, equipped with an L11 (3-11 MHz) linear array transducer. The transmitted ultrasound pulse bandwidth was set at 7-11 MHz. RF data were sampled in the ultrasound system at 39 MHz, 12 bits deep, and were transmitted to a workstation using a USB 2.0 interface.

The upper lip of the subjects was prepared by extruding approximately a one-centimeter layer of commercial ultrasound contact gel (Kendall Meditec, Mirandola (MO), Italy) over the full width of the upper lip in transversal scanning. Then the transducer was carefully applied to this layer while avoiding inclusion of air bubbles between transducer surface and gel (figure 1). During the acquisition, the subject was asked to slowly contract the lips by making a “kissing movement”. This movement is caused by contraction of the muscle orbicularis oris, which is positioned in the upper and lower lip as an elliptical structure. If this muscle is interrupted by scar tissue, this scar tissue will deform passively during contraction.

Cross-correlation analysis was used to calculate the strain along the ultrasound lines of successively acquired frames. Selection of frames was performed on basis of the real-time movie of the conventional echo images. Time delays between windows of 100 sample points were determined using the location of the peak of the cross-correlation function. Hundred-fold band-limited interpolation was used to increase resolution. The strain was calculated by applying a finite difference algorithm on the time delay signals. Successively acquired frames were used to keep strain values under 1%.

Results
Strain images could be obtained in all individuals. The echogram and strain image of the normal volunteers (figure 2) shows a layered structure. The superficial layer is compressing up to 1% while the deeper laying region, corresponding to the muscle, is expanding up to 1%. This expansion is caused by the contraction of the muscle in the direction perpendicular to the ultrasound beams. Since muscular tissue is not compressible, a contraction in a certain direction will result in an expansion in directions perpendicular to it. The compression of the superficial layer can be ascribed to passive stretching due to the pressure induced by the contracting muscle. In the strain image of a patient, the expanding region is interrupted (figure 3). The position corresponds to the region of the reconstructed cleft, as also indicated in the conventional echogram by the inhomogeneous echo pattern. This scar tissue region is compressing rather than expanding. This
opposite direction of deformation can be explained by the fact that the scar region is part of an elliptical muscle. If the muscle is contracting, the scar tissue is stretched, resulting in a compression of the material in the direction of the ultrasound beams. On the elastogram a larger scar region can be observed compared to the area indicated in the echogram. In the echogram, the scar tissue can be observed (figure 3, arrows) in the superficial tissue but not always in the muscle layer.

**Discussion**

This study demonstrates that axial elastograms can be obtained in healthy and reconstructed cleft lips. Deformation of the tissue is induced by active contraction of the individuals by making a “kissing movement”. The disadvantage of this technique is that the deformation is not well controlled. The rate of contraction and the maximum value of the contraction may differ substantially between subjects and, therefore, results of different patients will be hard to compare. However, for identification of the size of the scar tissue region in a single patient this might be of limited influence and qualitative elastography might be sufficient. The direction of deformation of the scar region with respect to the muscle region is the opposite. Therefore, a clear distinction between the two different tissue types can be made. For identification of the scar tissue in the superficial connective tissue layer, quantitative elastography might be beneficial. Furthermore, the mechanical properties of the scar tissue might be an important identifier of functional and esthetic outcome of the reconstruction. A second limitation of deformation caused by active contraction is the applicability in young children. Normally, reconstruction of the cleft lip is performed at very young age. At this age, deformation induced by a cooperative individual might be impossible.

For very young patients and for quantitative elastography, contraction of the muscle using an electrical stimulus might be an option. This technique is already widespread used for diagnosing neuro-muscular diseases. Selection of frames will also be done using this technique.
With the availability of 2D and 3D strain estimation techniques, the deformation of the tissue can be determined in more directions. Adding the lateral strain component to this method might improve the detectability of the scar region [5]. It is known, that muscle tissue is anisotropic whereas the scar tissue is supposed to be isotropic. This different tissue behavior could be obtained using 2D strain estimation techniques.

Finally, further validation is required to demonstrate that elastography of the lip is an adequate technique to routinely evaluate cleft lip reconstructions.

**Conclusions**

Elastography of cleft lips is feasible and yields information that is additional to the information from conventional ultrasound images. Different contraction patterns in normal and cleft lips are found. The scar tissue can be differentiated from the muscle since compression instead of expansion is observed.

**References**


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**Figure 3: Echogram (left) and elastogram of a reconstructed cleft lip.** In the normal echogram, the superficial tissue and the muscle can be identified. Although some differences in speckle can be seen in the right part of the muscle (arrows), the scar tissue is not clearly visible. The elastogram reveals an expanding region interrupted by a compressing region corresponding to the region of the scar. This region is larger in the elastogram than the region in the echogram.