In Vivo Stiffness Measurement of the Collateral Ligaments of the Knee Using Strain Ultrasound Elastography

Surangika Wadugodapitiya1,2, Makoto Sakamoto1*, Masaei Tanaka3, Yuta Sakagami4, Yusuke Morise5, Koichi Kobayashi1

1 Graduate School of Health Sciences, Niigata University, Niigata, Japan
2 University of Peradeniya, Peradeniya, Sri Lanka
3 Niigata Institute for Health and Sports Medicine, Niigata, Japan
4 Graduate School of Science and Technology, Niigata University, Niigata, Japan
5 Faculty of Engineering, Niigata University, Japan
* sakamoto@clg.niigata-u.ac.jp

Introduction. The medial (MCL) and lateral (LCL) collateral ligaments play a major role in stabilizing the knee joint against valgus and varus forces. Understanding of normal loading behavior of the collateral ligaments can aid in various clinical applications such as during knee arthroplasty, knee rehabilitation following ligament injuries and ligament reconstruction surgeries. Various methods have been described strain and stiffness distribution of the knee collateral ligaments using length change data1,2,3 however, a method of direct stiffness evaluation has not been reported. Therefore, this study was designed to assess the feasibility of ultrasound strain elastography (SE) for measuring relative stiffness of the knee collateral ligaments.

Materials and methods. The superficial MCL (sMCL) and LCL of 10 healthy volunteers (age 22.9 ±1.45 years) were assessed using SE with an acoustic coupler as the reference, while placing the knee in different flexion angles (Fig. 1). The ligaments were divided into proximal, middle and distal components during the elastography assessment. Relative stiffness of the ligament component was obtained using strain ratio ($SR = \frac{\text{target tissue strain}}{\text{reference strain}}$). Lower $SR$ indicates higher relative stiffness. The reproducibility of the $SR$ values was assessed through intraclass correlation coefficient (ICC) in 0° knee flexion position.

Results and discussion. The intra-rater ICC(1, 3) of the $SR$ values showed good to excellent reliability and the inter-rater ICC(2, 3) showed substantial agreements in all the components of the sMCL and LCL.

The $SR$ values of all the components of the sMCL and LCL were minimum at the 0° knee flexion. In the sMCL, $SR$ was relatively constant from 0 – 60° and thereafter, it increased rapidly when reaching 120° knee flexion. The $SR$ values of the LCL showed a fluctuating tendency with increasing of the knee flexion angle.

The relative stiffness found to be more in the sMCL compared to that in the LCL from 0 – 60° however, at 120°, the LCL was stiffer than the MCL (Fig. 2).

The stiffness tendency of the collateral ligaments with knee flexion observed in the present study is in accordance with previously reported data2,3.

Conclusion. The present study established a feasible and reproducible method to obtain real-time information on tissue stiffness of the knee collateral ligaments using SE which can be easily applied in the routine clinical practice. Stiffness behavior of different components of the collateral ligaments varied with knee flexion angle.

References.