Mechanics of Needle-Tissue Interaction

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Abstract

When a needle is inserted into soft tissue, interaction forces are developed at the needle tip and along the needle shaft. The needle tip force is due to cutting of the tissue, and the force along the needle shaft is due to friction between needle and tissue. In this study, the friction force is determined for needles inserted into a gelatine phantom at insertion velocities of 10 mm/s and 20 mm/s. The friction force is found to be dependent on the insertion velocity. The needle tip force is calculated using the friction and insertion force, and is used as input for a mechanics-based model which predicts the amount of needle deflection. In the model, the needle is considered to be a cantilever beam supported by springs which have needle-tissue interaction stiffness (K_e). The value of the interaction stiffness is evaluated by comparing results from experiments and simulation. Needle insertion experiments are performed using gelatine as soft tissue phantom. A mechanical needle insertion device is used to insert needles. Needle deflection during insertion is determined using a needle tip tracking algorithm. Results of this study provide insight into the mechanics of needle-tissue interaction, and can be used in studies for robotically steering needles into soft tissue.