CONFORMABLE SENSOR TECHNOLOGY AND THE FUTURE OF SURGICAL TRAINING AND SIMULATION: FROM MEDICAL LAPAROSCOPIC AND ROBOTIC MANIPULATION TRAINING MODULES, TO SMART ANATOMICAL AIRWAY INTUBATION TRAINING SIMULATORS

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7-SIGMA
TRANSCENDING EXPECTATIONS

BACKGROUND & MOTIVATION

Conformable Sensor Technology represents a precise, inexpensive, and customizable substitute to standard resistive and capacitive sensors. Analogous to resistive sensors, a voltage divided circuit can be used to operate the sensor. Unlike resistive sensors, conformable sensors are silicon-based, single-material units that can operate in ranges covering 8-orders of magnitude of force. Conformable sensors can be manufactured to satisfy spatial and loading constraints alike. 7-SIGMA and The Center for Research in Education and Simulation Technologies (CREST) are currently collaborating toward the implementation of these sensors in a variety of applications, within the field of medical training.

OBJECTIVES

The development of inexpensive, reliable, and interactive training modules for Laparoscopic, Manual, and/or Robotic Surgical procedures.

PRELIMINARY RESULTS

Three Laparoscopic and Robotic Manipulation training modules and one Smart Anatomical Replica were developed using Conformable Sensor Technology, Arduino Mega, and the Arduino Processing language for Graphical User Interfaces.

MOVING FORTH

The manufacturing of conformable sensors must be standardized. Manufacturing protocols must be established based on a thorough characterization of the sensor's material properties.

TRAINING MODULES AND MODELS

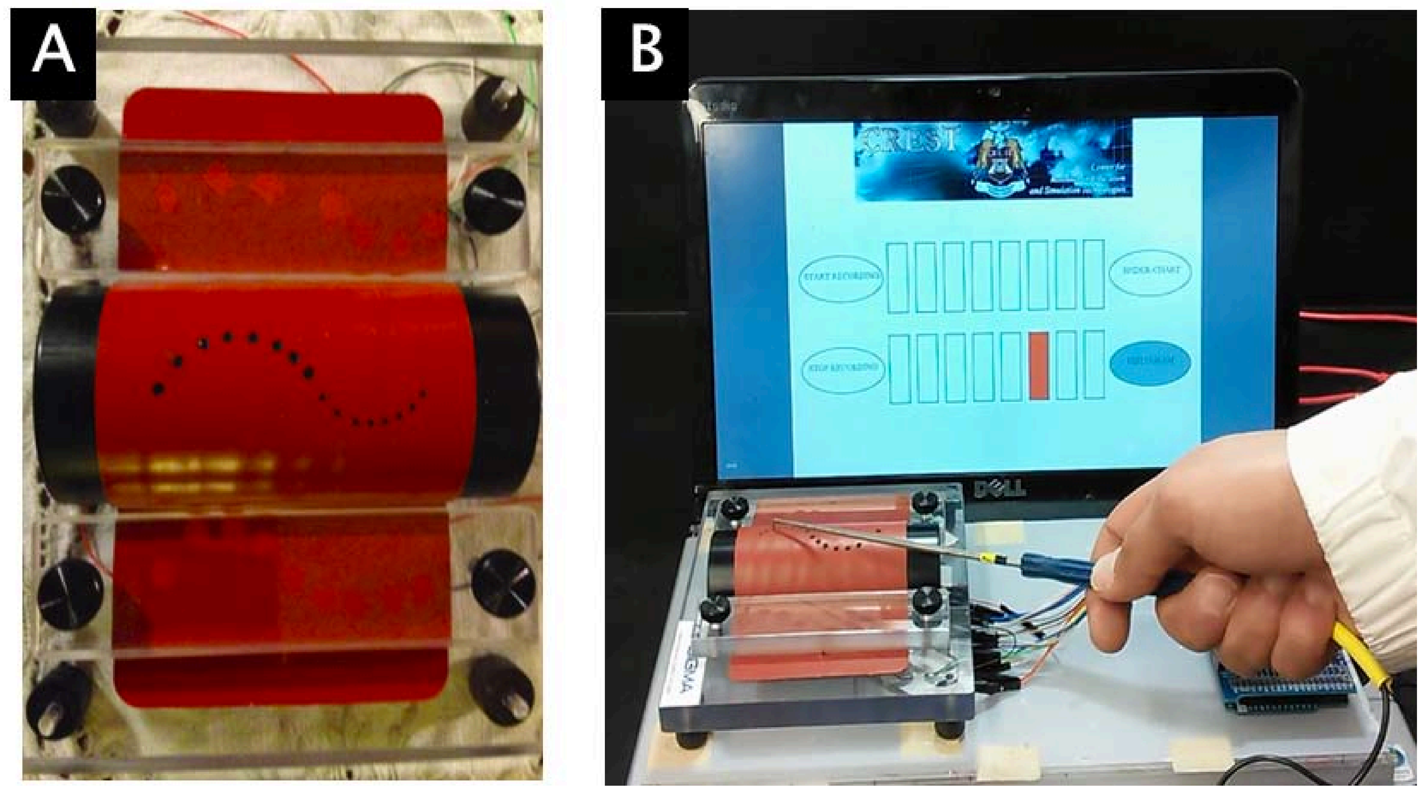

Figure 1: Laparoscopic Dexterity Skills Training Module

Conformable Sensor Technology can be used to create thin (100µm – 1mm), touchpad sensors. Independent sensors can be assembled into patterns for Laparoscopic Dexterity Skills training [Figure 1-A]. In the most simple training scenario, the trainee must make contact with the assigned targets. Contact precision and time for exercise completion can be used to asses the performance of the trainee. In addition to contact, the resistance changes of the sensors can be used to measure the magnitude of the force applied on the pad. Graphical user interfaces (GUIs) have been built in order to collect and translate these resistance changes [Figure 1-B].

Additional sensors can be layered in order to increase the complexity of the training module. Suturing and Wound Closure models assess suture perforation and even load distribution, across the wound, during suturing [Figure 2-A]. Cutting training modules consist of complicated paths delimited by conformable sensors [Figure 2-B]. As the trainee cuts through the sensor, the resistivity change can be related to the position along the path. Layered sensor can also provide the trainee with depth-of-cut information, essential measurement for dissection of multilayered organ models.

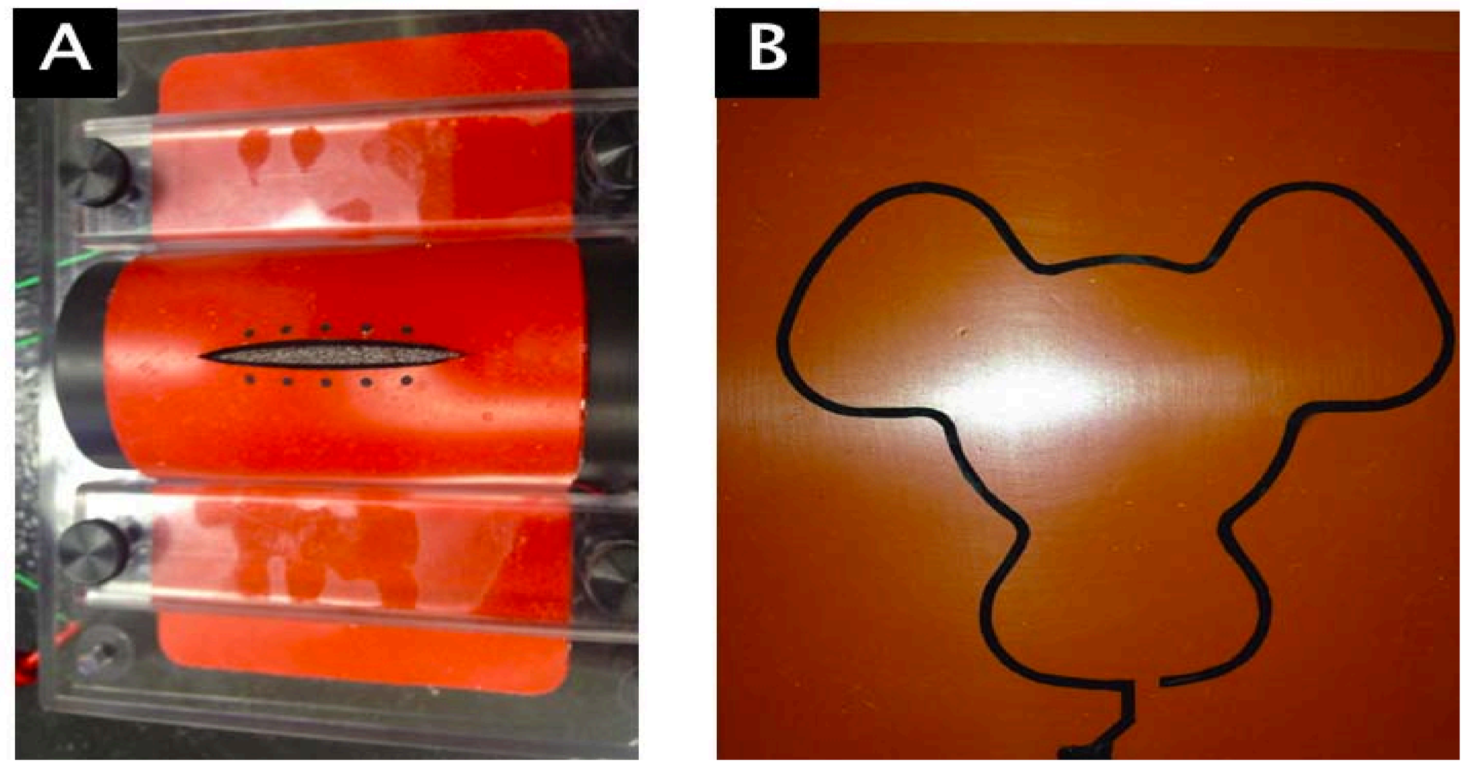

Figure 2: Wound Closure [A] and Cutting [B] Training Modules

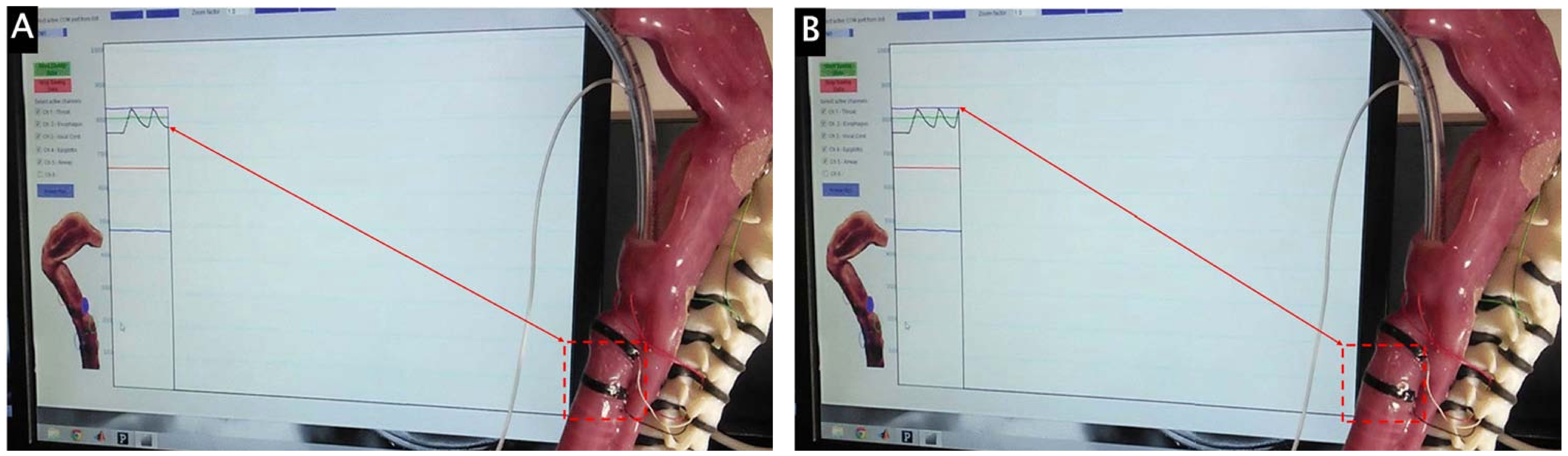

Figure 3: Anatomically-accurate, three-dimensional reproductions have been equipped with conformable sensors to create Smart Anatomical Reproductions. Procedure-specific models have been created for training. The airway model [A-B] has been created to train proper patient intubation.

Design flexibility, sensitive, and layering has allowed for their implementation of Conformable sensors within Smart Anatomical Reproductions (SAR). Conformable sensors are embedded into the silicon-based, airway SAR to measure localized strains and stresses during intubation. More involved graphical user interfaces (GUI) were built to measure the dynamic loadings imposed on the model. In a relax or unloaded configuration, the sensor around the trachea experiences no strain and, thus, no change of resistivity [Figure 3-A]. When the trainee inflates the balloon to secure the intubation catheter, the expansion of the tracheal walls generate a strain on the tracheal sensor and, thus, a change in its resistivity [Figure 3-B]. Cyclical strains, common in biological tissues, can be perceived by the sensors with accuracy and repeatability.