Smart Laparoscopic Training Modules
Conformable Sensor Technology

7-SIGMA, Inc   UMN SimPORTAL CREST

Conformable Sensor Technology has been applied to Medical Laparoscopic & Robotic Manipulation Skill Training to measure proficiency of psychomotor, suture placement, wound closure and arterial surgical skills. Performance measurement results from the response of the sensor recorded by the control processor unit and displayed in graphical mode as well as formatted into a CSV file for assessment purposes.

Laparoscopic and robotic manipulation skills are measured for the ability of accurate placement of the suturing needle onto 2 mm spots placed in an "S" pattern on a surface. Conformable sensor material is placed onto each spot to provide a contact point that records the placement of the needle to the spot. The force that is exerted onto that spot can also be ascertained. The exercise is timed and the contact time to each spot is graphically shown and mapped to a CSV file for evaluation. Figure 1 shows a training module that contains 16 points which the student must accurately contact with a needle manipulated laparoscopically within a training box. The output of the sensor is controlled by a 16 channel Arduino CPU whereby each spot is assigned a single channel.

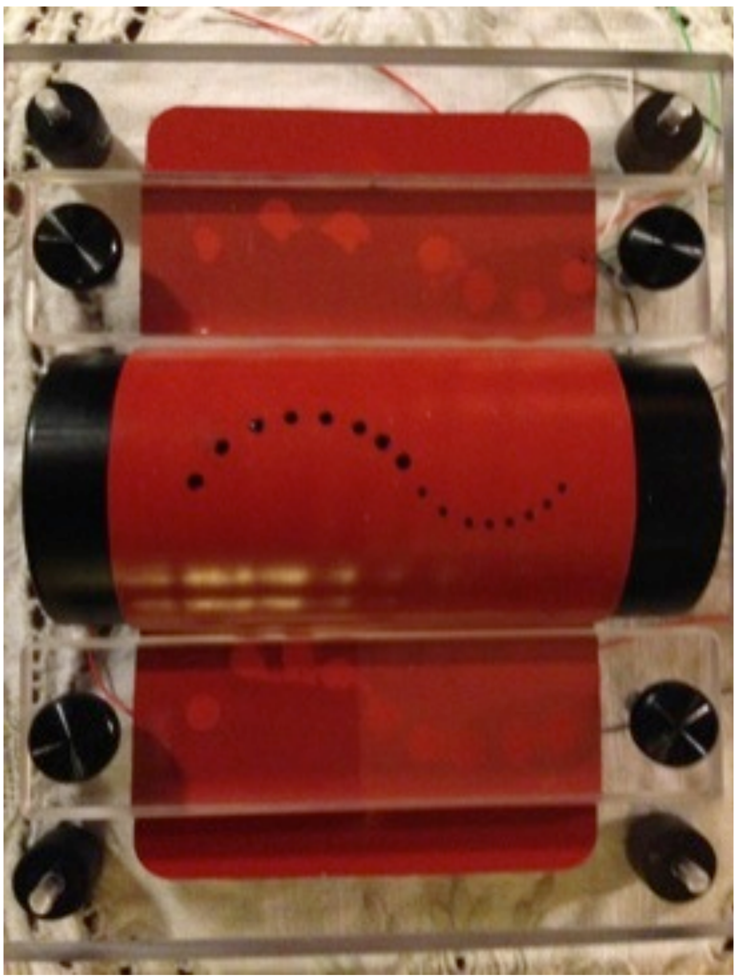

Fig. 1 Laparoscopic Suture Placement Exercise

A follow on skill in training involves laparoscopic suturing of a "wound" such that the accurate placement of the needle to two points under the "skin" and the resultant wound closure are measured by the conformable sensors. Figure 2 shows a training module for wound closure that consists of a "skin" with an open wound. In this example, five suture points are designated by the spots on each side of the opening. The "skin" is layered such that the sensor material is located under each of the spots at several levels, and on each side of the open wound. The student must accurately place the suture needle onto the indicated spots and then penetrate the skin accurately to a specific location and depth. The needle then must be maneuvered so that a specific spot on the opposite side of the wound is located and penetrated back to the surface of the skin. The sensor records if contact has been made at those designated points. As the suturing closes the wound the closure contact is recorded. The sensors not only indicate that the closure has taken place, but also the pressure applied at each suture point. Also from the data, an indication of alignment can be determined for training assessment. Figure 2 show a graphical response of a simulated close and opening of the wound area in three distinct steps (by hand).

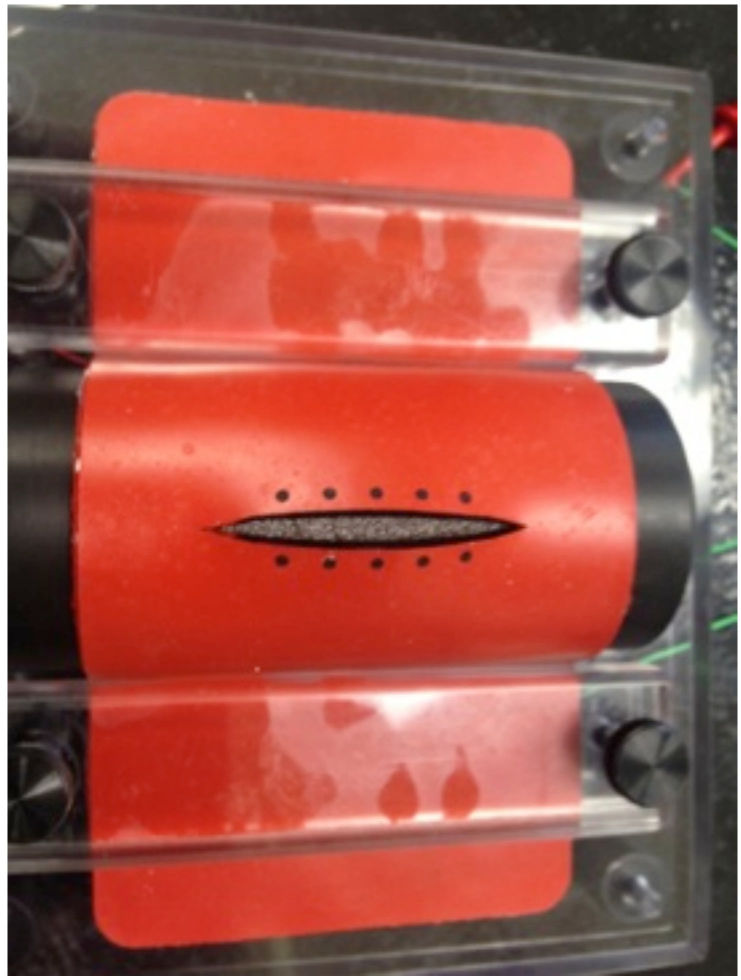

Fig. 2 Wound Closure Training Module for Laparoscopic Suturing Exercise

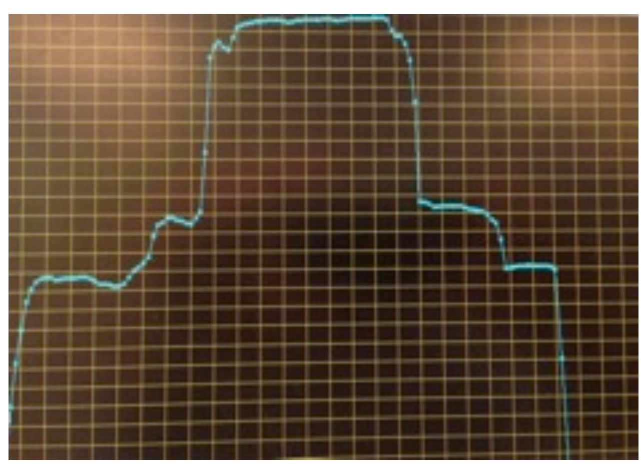

Fig. 3 Sensor response to closure and opening of the "wound" in three steps.

Psychomotor surgical dissection tasks measure the accuracy of cutting within a prescribed track by determination of the proper depth of dissection and the placement within the boundary of a path. Figure 4 is an example of a training device whereby Conformable Sensor Technology material determines the "out of bounds" conditions, the depth, and the pressure of the dissection performed by the student. The path along which the dissection takes place is a 2 millimeter wide strip of sensor material that is placed on several layers of the "skin" in a designed pattern. The distance along the path from the starting point is determined by the change in resistance of the sensor from the start point, thus time and placement of the dissection task, as well as "out of bound" conditions are determinable. Figure 5 is a graphical display of the distance from the start point of several consecutive insertion/ removal of a knife along the path. Insertion of the knife completes the electrical circuit. At the point of insertion the resistance of the sensor material is a function of the distance from the electrode. The further distance from the electrode the greater the resistance. The cutting distance is about 2 cm for each section shown between "insert" and "remove". The increase in the slope between "insert" and "remove" shows the distance the knife traveled through the sensor. From this data, the proficiency of the student to perform the dissection task can be assessed with digital data. The tasks include not only staying on the prescribed line, but also the depth of the cut and even the pressure applied.

Fig. 4 Laparoscopic Robotic Manipulation Skill Training Module.

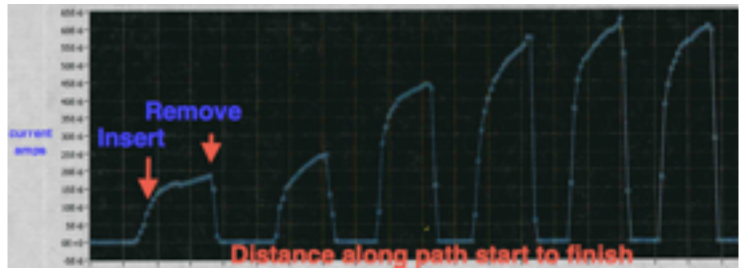

Fig. 5 Cutting application display. Insertion/Removal of knife along cutting path.

Conformable sensor technology has also been applied to training of artery clamping and clipping. Measurement of the clamping force, and successful closure of the clamped artery is determinable from the output of the sensor. The sensor is totally integrated into the silicone rubber artery, responding to the pulsed water, emulating the blood flow through the artery, and the clamping forces applied to the synthetic artery. Figure 6 shows the display of the graphical response of the "pulse" of the blood through the simulated artery and resultant clamping of the artery.

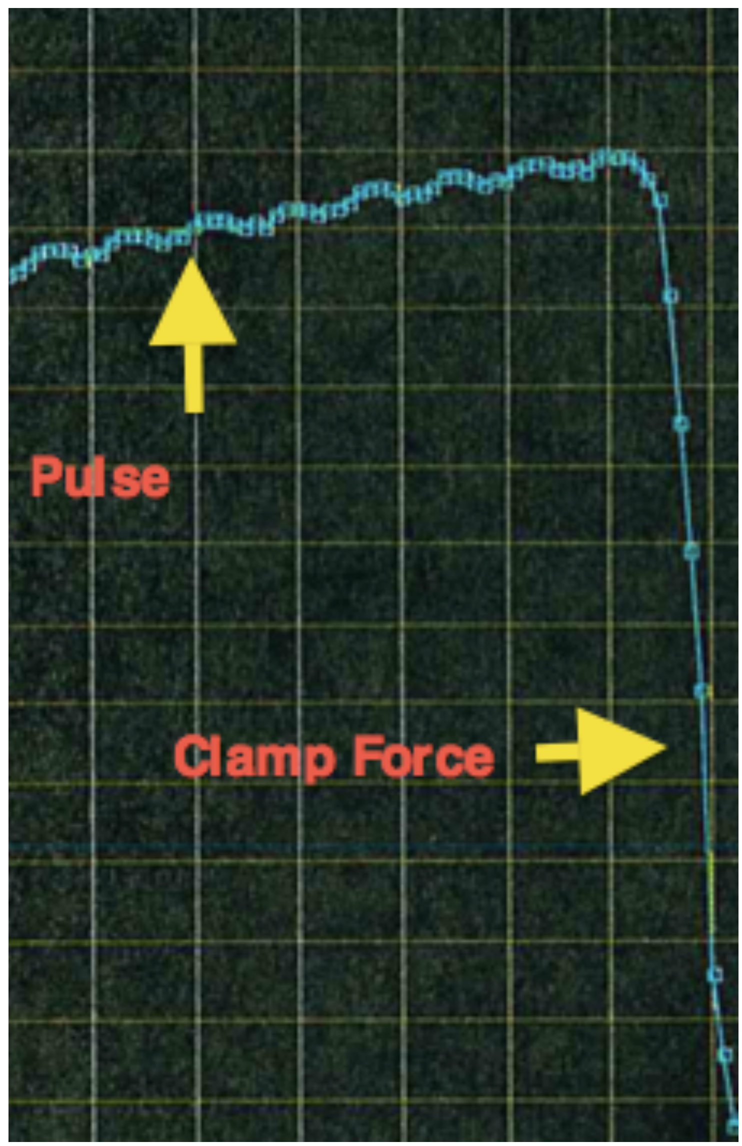

Fig. 6 Graphical display of pulsed artery clamping and the resultant force response of the conformable sensor within the simulated artery.