

SENTISIM: A hybrid training platform for SLNB in local melanoma staging

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INTRODUCTION

Sentinel Lymph Node Biopsy (SLNB) has been established as an accurate procedure for regional melanoma staging. SNLB has a diagnostic significance as biopsy-based staging identifies patients with nodal metastases who may benefit from immediate complete lymphadenectomy and prolongs disease-free survival for all patients. Among patients with intermediate-thickness melanoma, this procedure provides significantly improve, over the 10-year disease-free survival rate, compared to the lymphadenectomy for nodal relapse (71.3±1.8% vs. 64.7±2.3%). This improve is also observed among patients with thick melanomas (50.7±4.0% vs. 40.5±4.7%) [1].

Optimal SLNB combines radionuclide and blue dye detection to identify the sentinel node and, during the procedure, a hand-held gamma probe is used to locate the sentinel nodes for their extraction [2]. These skills are unfamiliar to many surgeons and inexperience could lead to misdiagnosis, and thus follow an inadequate treatment, and increasing costs at the long term. Previous studies recommend a minimum of 30 cases as training phase to master SNLB due to its characteristic learning curve [3]. The estimated cost of educating a surgeon simply in added time in the operating room has been estimated at about \$50.000 during the five-year residence period [4]. Surgical training platforms have emerged in the latest years as an alternative to enhance surgical training outside the operating room and even to certify procedure knowledge and ability. Up to date, some physical training models have been reported using synthetic material [5][6] or a human cadaver torso [7]. The main problem with those models is the use of radionuclide, such as technetium-99m (^{99m}Tc), that entails a security protocol requirement and high costs. In addition, these platforms lack evaluation metrics to measure the exercise quality and that can worsen the training evaluation. Virtual training platforms allow to practice a surgical procedure, while they gather data of the performance to evaluate the quality of the exercise. Their main disadvantage is the loss of real feedback, which can drive to an unrelated perception of the real procedure.

Training platforms, virtual or physical, are a perfect complement to conventional training such as dissection practices that usually provide limited availability and result in high cost. The use of these platforms reduces the risk of complications and the cost of training. This work presents a new training platform for SLNB in local

melanoma staging, that solves the previous problems maintaining a realistic scenario, at the same time that measures a series of important parameters to determine the quality of the surgery.

MATERIALS AND METHODS

SENTISIM is a hybrid simulation platform for training and evaluation of SLNB that combines a virtual and a physical environment, taking the advantages of both approaches. SENTISIM allows the user to train the key aspects of SNLB in a realistic scenario: hand-held gamma probe navigation, node identification, tissue dissection, node extraction and final suture. In addition, the system allows the practice of critical situations like vascular suture for femoral artery accidental dissection.

The system consists of three main modules: a multi-layer pad that simulates the inguinal region; a custom hand-held active navigation probe for node detection, and a software application to receive, analyze and store data from different sensors (e.g. probe), to generate signals for pad actuators and user interface.

The inguinal module is an anatomically realistic multi-layered pad constructed using advanced soft plastic and silicon materials reproducing textures and dynamic properties. The multi-layer composition simulates skin, fat, fascia and subcutaneous tissue, muscle, tendons, nerves, blood vessels and lymph nodes (Fig. 1).

The surgery is performed on the anatomic pad using real tools and provides realistic feedback of the passive behaviour from the different anatomic structures. Active behaviour such as cardiac pulse or muscular contractions caused by local nerve stimulation are also simulated.

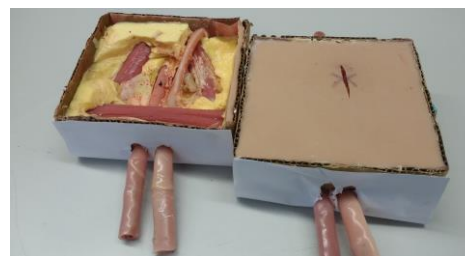


Figure 1. Section and full views of the multi-layer pad.

The custom hand-held probe (Fig. 2) simulates the gamma probe, and is used to identify and locate the nodes inside the anatomic pad. The target sentinel nodes have miniaturized magnets inserted. The simulation of the node detection is carried out through a magnetic sensor (Hall effect) located at the tool tip, that detects the

magnetic emission of the node reproducing the behaviour of the gamma probe when detecting radionuclide. More magnetic elements are present in the platform to simulate the background count and residual detection. The probe provides acoustic and visual feedback of the sensor value to improve node detection understanding. Tracking of the probe is done using an 9DoF IMU. Sensors data is sent to the user interface to enhance the training experience and later evaluate the navigation performance.



Figure 2. Hand-held gamma probe simulation module.

The software (virtual part of the system) collects all the data from the sensors, guides the exercise through a user interface which displays the counting of the detection probe along with its reference value and other information such as like heart beat signal, vascular circuit blood level and nerve integrity (Fig. 3). Once finished the exercise, the software evaluates the training session through performance data. Gathering information of the training and comparing over evaluation metrics is essential to measure the quality of an exercise. The evaluation metrics considers time, precision of detection, probe sweeping area, correct node extraction and accidents (vessel or nerve cut). This evaluation is combined with an ocular inspection from a supervisor.



Figure 3. First version of SENTISIM user interface.

RESULTS

The presented platform, that is under patent process, has been tested in the 2nd edition of MelaTX; a 3-day workshop in Sevilla (June of 2018) focused on a full review and training of medical-surgical treatment of locally advanced melanoma. Twenty-two dermatologists (resident and experienced) from various Spanish hospitals participated in this test. The test was performed in a two-round practical session where the participants worked in pairs, one assuming the role of the surgeon and the other that of an assistant. In the second round, the roles were exchanged. Evaluation metrics gathered during the practice permitted a better overall assessment of the exercise. E.g., tracking of the probe provided a density map of the navigated zone, where the hot spots coincide with the location of the nodes (Fig. 4). Compared to a pre-operative gammagraphy can give a matching percentage. A small group of experts, that were invited to the workshop as speakers tested and validated the platform. The feedback received from the participants remarked the realism of the platform from the node

identification and the surgical procedure on the pad. The majority expressed an increase in self-confidence in their SLNB skills. Usability tests will be done in near future to analyze impact in learning curves.

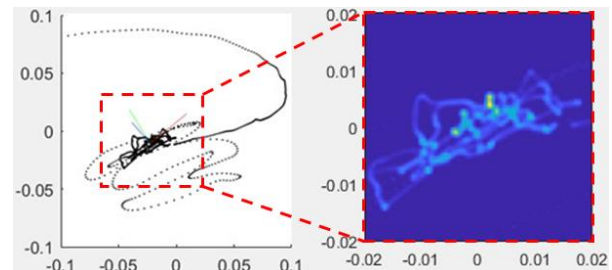


Figure 4. Tracking of the probe (left) and density map (right).

CONCLUSION AND DISCUSSION

This paper has presented SENTISIM training platform for SLNB. The platform combines virtual and physical advantages thanks to its modular approach. Its main characteristics are realism, tissue behaviour, continuous feedback interaction, probe navigation, etc. The platform allows performing a complete surgical procedure, training all main key aspects and emergency situations. Avoiding the need of radionuclide material usage for node detection eases the access to training sessions thanks to its reduced costs and security protocols. SENTISIM has demonstrated its validity during the MelaTX course. A group of 22 participants and another of 8 experts performed the practical session using the platform. SENTISIM obtained the face-validity from the experts group.

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