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Editorial

Soft Robotics: An Innovative Strategy for Management of Cancer

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Soft robotics is an amalgamation of engineering, material sciences, and biology that are merged to produce robotic structures that are flexible, reconfigurable, and inspired by natural organisms. Soft robots are better than their rigid counterparts in many ways. The flexibility expands their usage in medical scenarios such as diagnostics or treatment procedures [1]. For instance, it has advantages for cancer detection alone or when combined with other imaging devices. They possess a variety of sensing technologies incorporated, such as optical sensors [2], spectroscopic probes [3] and microfluidic channels [4], which allow for on-the-spot and noninvasive identification of cancerous lesions or biomarkers. Moreover, their malleable nature enables these robots to navigate through intricate human body anatomy with no or minor inconvenience to the patients concerned and less impact on tissues.

McCandless et al. reported on a controlled robot to diagnose lung cancer. It had a small diameter of 2.4mm, ensuring deeper penetration into the lung branches than existing ones. Mechanical evaluations like blocked force, bending angle, angular velocity, and workspace validated the robot's in vitro and ex vivo performance. The computer vision algorithm also assisted the clinician in navigating through a user-friendly interface by autonomously aligning the robot with targeted lung branches. Moreover, robot-aided lesion stabilization via automated tracking and alignment improves diagnostic accuracy and interventional efficacy in detecting lung cancer [5]. Ho et al., utilized Monarch as their robotic-assisted bronchoscopy during pulmonary lesion sampling using arterial signs [6]. The Ion Endoluminal System is an example of such technology that is designed as an assistive technology for shape sensing in patients with small peripheral pulmonary nodules (PPNs). The system has RAB, 3D mapping, flexible catheter, peripheral vision probe, and biopsy needles; it was evaluated in 241 patients with 270 PPNs and showed promising results, including a reduction in the meantime for registration and navigation over cases. Minor complications involving asymptomatic pneumothorax were reported at a rate of 3.3% among patients, and airway bleeding was noted at 0.8%. This unique technology could help improve the localization and sampling of PPNs, which may increase the efficiency of diagnosis [7].

A soft robot prototype, the MAMMOBOT, was developed to look inside mammary ducts and identify any tumors. The design of this innovation is aimed at helping with more efficient early detection and diagnosis of breast cancer by ensuring that thorough and exact tests are done [8]. Scientists have developed microengineered soft-robotic platforms to perform simulated bending motions characteristic of tubular organs as well as apply controlled compressive forces on living cells. This novel elastomeric actuator was integrated with human cell cultures to provide a more natural environment mimicking the human body. Cyclic compressions involving endothelial cells and smooth muscle cells led to changes in cell morphologies, as observed by the researchers. The effects of compressive forces on three-dimensional tissue constructs such as solid tumors and vascular networks were studied using the same platform, and these findings showed their potential for moving mechanobiology forward [9]. Such advanced robots are designed specifically for studying distant metastatic processes, which is a crucial area associated with treatment failures most often. Their minuscule design makes it possible to conduct accurate diagnoses to increase our understanding and management of this challenging part of cancer.

Another study demonstrated the colon-specific soft robotic device that has been designed so that it moves and has structures similar to an earthworm, thus enabling its navigation through narrow spaces and delicate conditions within the colon. In the shape of an elephant trunk, the sampling mechanism could be flexed in two ways to collect samples. This innovative tool provided a non-invasive means for inspecting and sampling the colon, which boosted efficiency and accuracy in diagnosing intestinal conditions such as colorectal cancer [10]. These soft robots have also been developed into prototypes using in vitro, in vivo, and ex vivo approaches, as well as various models of cancers by constructing them, changing their designs, and making them acceptable for application in clinics. In addition to diagnostic applications, these robots can deliver drugs to target organs or tissues. Beatty and team demonstrated the Fibrosensing Dynamic Soft Reservoir (FSDSR), a device that monitors continuous drug dosing and formation of fibrotic capsules in a rodent model. The device could adapt to the biological environment by dynamic changes made in the soft robot connected to it [11]. (Fig 1)

Although soft robots promise more than one method for detecting many types of cancer, they also present significant roadblocks when applied clinically. These challenges can only be addressed holistically, encompassing miniaturization, seamless integration of sensing technology, prioritization of biocompatibility, careful selection of external navigation controls, and adept navigation through intricate biological. Furthermore, regulatory approval, cost-effectiveness, and patient acceptance should be carefully evaluated when developing and deploying soft robotic systems for healthcare applications. Despite these limitations, integrating soft robotics in cancer diagnosis holds immense potential for enhancing patient outcomes and reducing healthcare disparities. Soft robots can leverage their unique capabilities for non-invasive and real-time detection and monitoring of lesions, aiding clinicians in early detection, prompt intervention, and developing personalized treatment strategies tailored to individual patient needs.

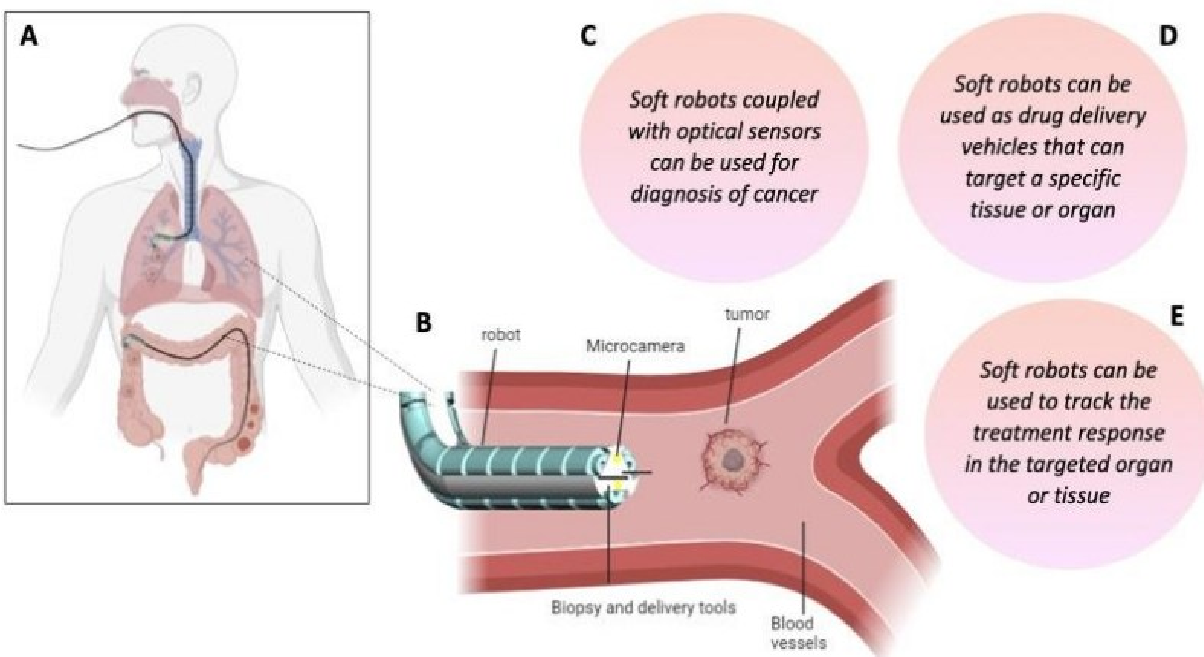

Figure 1: (A) Schematic representation of soft robot traversing the bronchioles and other hard-to- reach areas of the human body, (B) Magnified view of the robot at the tumor site, showing the robot's micro camera, biopsy, and delivery tools (C-D) Potential applications of soft robots in the field of oncology

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