Bio-inspired robotic sock that promotes blood circulation and prevents blood clots in legs

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NUS researchers (from right to left) Assistant Professor Raye Yeow, Mr Low Fanzhe and Dr Liu Yuchun demonstrating the novel bio-inspired robotic sock. Credit: National University of Singapore

Patients who are bedridden or unable to move their legs are often at risk

of developing Deep Vein Thrombosis (DVT), a potentially life-threatening condition caused by blood clots forming along the lower extremity veins of the legs. A team of researchers from the National University of Singapore's (NUS) Yong Loo Lin School of Medicine and Faculty of Engineering has invented a novel sock that can help prevent DVT and improve survival rates of patients.

Equipped with soft actuators that mimic the tentacle movements of corals, the robotic sock emulates natural lower leg muscle contractions in the wearer's leg, thereby promoting blood circulation throughout the wearer's body. In addition, the novel device can potentially optimise therapy sessions and enable the patient's lower leg movements to be monitored to improve therapy outcomes.

The invention is created by Assistant Professor Lim Jeong Hoon from the NUS Department of Medicine, as well as Assistant Professor Raye Yeow Chen Hua and first-year PhD candidate Mr Low Fanzhe of the NUS Department of Biomedical Engineering.

Bio-inspired approach to preventing DVT

Current approaches to prevent DVT include pharmacological methods which involve using anti-coagulation drugs to prevent blood from clotting, and mechanical methods that involve the use of compressive stimulations to assist blood flow.

While pharmacological methods are competent in preventing DVT, there is a primary detrimental side effect – there is higher risk of excessive bleeding which can lead to death, especially for patients who suffered hemorrhagic stroke. On the other hand, current mechanical methods such as the use of compression stockings have not demonstrated significant reduction in DVT risk.

In the course of exploring an effective solution that can prevent DVT, Asst Prof Lim, who is a rehabilitation clinician, was inspired by the natural role of the human ankle muscles in facilitating venous blood flow back to the heart. He worked with Asst Prof Yeow and Mr Low to derive a method that can perform this function for patients who are bedridden or unable to move their legs.

The team turned to nature for inspiration to develop a device that is akin to human ankle movements. They found similarities in the elegant structural design of the coral tentacle, which can extend to grab food and contract to bring the food closer for consumption, and invented soft actuators that mimic this "push and pull" mechanism.

By integrating the actuators with a sock and the use of a programmable pneumatic pump-valve control system, the invention is able to create the desired robot-assisted ankle joint motions to facilitate blood flow in the leg.

Explaining the choice of materials, Mr Low said, "We chose to use only soft components and actuators to increase patient comfort during use, hence minimising the risk of injury from excessive mechanical forces. Compression stockings are currently used in the hospital wards, so it makes sense to use a similar sock-based approach to provide comfort and minimise bulk on the ankle and foot."

The sock complements conventional ankle therapy exercises that therapists perform on patients, thereby optimising therapy time and productivity. In addition, the sock can be worn for prolonged durations to provide robot-assisted therapy, on top of the therapist-assisted sessions. The sock is also embedded with sensors to track the ankle joint angle, allowing the patient's ankle motion to be monitored for better treatment.

Said Asst Prof Yeow, "Given its compact size, modular design and ease of use, the soft robotic sock can be adopted in hospital wards and rehabilitation centres for on-bed applications to prevent DVT among stroke patients or even at home for bedridden patients. By reducing the risk of DVT using this device, we hope to improve survival rates of these patients."

Plans for clinical studies and commericalisation underway

To further investigate the effectiveness of the robotic sock, Asst Prof Lim, Asst Prof Yeow and Mr Low will be conducting pilot clinical trials with about 30 patients at the National University Hospital over six months, starting March 2015. They hope that the pilot clinical trials will help them to obtain patient and clinical feedback to further improve the design and capabilities of the device.

The team intends to conduct trials across different local hospitals for better evaluation, and they also hope to commercialise the device in future.

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