Design of a Novel Robotic Assistant System for Endovenous Laser Ablation for the Treatment of Varicose Veins

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Abstract: A novel robotic assistant system has been proposed for endovenous laser ablation for the treatment of varicose veins. This robotic system is composed of wire insertion mechanism and temperature measure system. It can automatically pull the laser wire out of the lesions intravascular according to the endovenous temperature while heating and ablating the intravascular with laser. The working principle and control diagram are also introduced. This system will help to heat the intravascular precisely according to the temperature so as to reduce the rate of transmural vein wall injury and recurrence. Besides, this robotic system can help to reduce the operation complexity and operation time of endovenous laser ablation.

1. Introduction

Varicose veins affect up to 32 per cent of women and 40 per cent of men [1]. Ligation of the greater saphenous vein GSV) at the saphenofemoral junction (SFJ) and stripping of the vein has been the standard of care for varicose veins. However, ligation/stripping has a recurrence rate of up to 40% at 5 years; 20% of varicose vein operations are for recurrence [2]. Endovenous laser ablation (EVLA) has emerged as an effective minimally invasive treatment of lower extremity superficial venous reflux disease and has largely replaced surgical vein stripping as first-line treatment for superficial venous reflux, durable with a persistent closure rate of 95–97% [3]. As to EVLA, the most important factor that affect the outcome is the quantity of laser energy released on the wall of the varicose. [4]That is, overdose energy will cause to transmural vein wall injury, and insufficient energy may cause recurrence. Currently, most devices for EVLA have no energy feedback, so surgeons have to estimate the heating energy with their experience. This may cause mistake and failure for the treatment. Besides, it retreat the EVLA method to those well trained surgeons and limits the popularity of it. So it is very necessary to measure that quantity of the laser energy released in the varicose.

In this paper we propose a measure system to settle the problem above and further we introduce a novel robotic system to assist the surgeon to perform EVLA which will definitely reduce the complexity of it.

2. System configuration

A novel robotic assistant system for EVLA is developed, as showed in fig.1. The system is composed of a wire insertion mechanism and a temperature acquisition system. They are assembled into a case with control unit in it and a touch screen interface on it. Besides, there is a emergency button for safety.

The working principle is showed in fig.2. During the EVLA process, the surgeon first put the temperature sensor and the laser fiber into a guide tube, and set it well between the two guiding wheels. Secondly, the surgeon inserts the tube into the varicose manually. After the tube reaches the end of the varicose, it is ready to turn on the laser system and the robotic assistant system. While the laser it heating the varicose wall, the temperature in the varicose rises. At the same time, the temperature sensor acquits the temperature and feed it back to the intelligent control unit. When the temperature reaches the mean value which is perfect for the EVLA, signal will send to drive the motor and drive the guiding wheel to pull the tube some distance, 3mm or example, out along the varicose. This is a control cycle and this will repeat until all the tube is pulled out of the varicose when the robotic assistant EVLA process is completed.

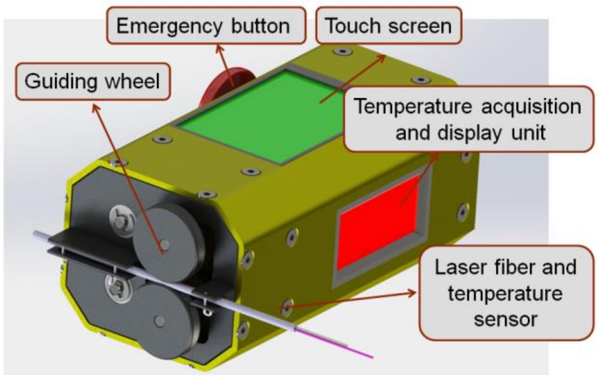

Fig.1. Configuration of the robotic assistant system.

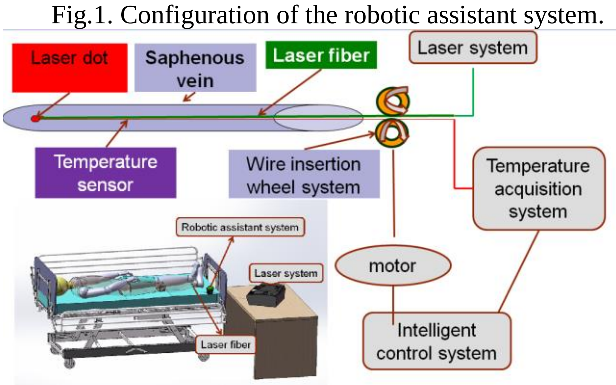

Fig.2. Framework of the robotic assistant system.

We can see from the working scheme above that the surgeon only has to insert the tube into the varicose, after that the robotic assistant system will perform the EVLA automatically and precisely.

3. Insertion mechanism

Actually, the insertion mechanism does not work during the insertion process; it works reversely to pull the tube with laser fiber and temperature sensor in it out of the varicose. The insertion mechanism is drive by a blushed servo motor. As show in Fig.3, two pairs of gears were assembled on lever1 and lever2. Meanwhile, gear1and gear2 couple together. Thus, when gear1 is drive by the motor, through this gear transmission system, the two guiding wheel will rotate in opposite direction. With friction force the wheel guides the tube forward or backward. Besides, a spring links lever1 and lever2 to guarantee the pressure between the two guiding wheels. Two guiding grooves are attached on both sides of the guiding wheels to keep the direction of the tube and prevent the tube from sliding out of the two guiding wheels.

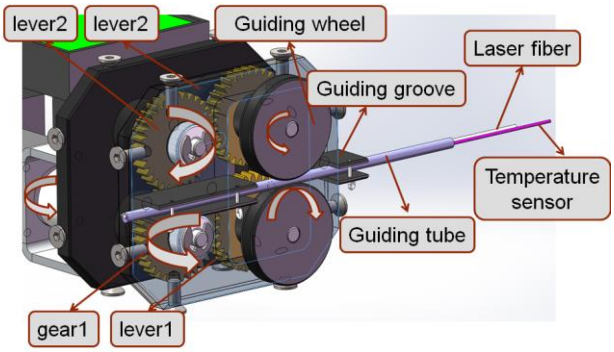

Fig.3. Insertion mechanism of the robotic assistant system.

4. Control algorithm

We develop an intelligent control algorithm for the robotic assistant system, as showed in Fig.1. During the whole EVLA process, the laser is heating the varicose with constant energy. Instead of trying to control the power of the laser energy, we control the laser energy released on every point along the varicose. For temperature control, we develop a bang-bang controller. We set a throttle value for the controller. At a heating point, if the temperature is under that value, the laser dot will hold at the point and heat. When the temperature reaches that value, it will set a new point for heating some distance away along the varicose.

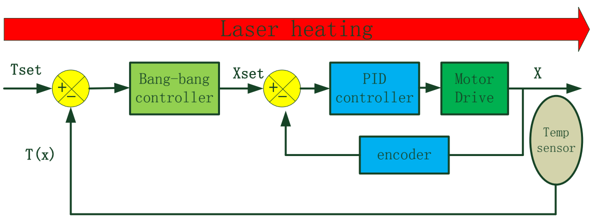

Fig. 4. Control framework of the robotic assistant system.

Insider the temperature control loop, we also develop a position control loop for control the moving distance precisely in every cycle. We use a optical encoder for position and velocity feedback.

5. Experiment result

We carry out an experiment for the robotic assistant system. In this experiment, we use a brass tube instead of a real varicose. First, for verifying that our mechanism and control algorithm works, we use a clerical iron instead of the laser dot to heat along the brass tube and collect data of position and temperature. The experiment platform is showed in Fig.5. Then we draw a response curve using this data. The curve is showed in Fig.6.

Fig.5. Experiment of the robotic assistant system.

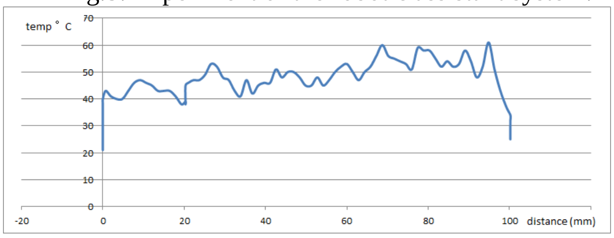

Fig.6. The response curve of the robotic assistant system.

We can see from this curve that the temperature is quiet uniform and steady during the moving of the electrical iron. This result verifies that our mechanism and algorithm works well.

6. Conclusion

We proposed a novel robotic assistant system for endovenous laser ablation for the treatment of varicose veins. We also developed an intelligent algorithm to control it. Experiment shows that it works quiet well. Further we will carry out some experiment on aminals.

References

[1].Evans C, Fowkes FG, Ruckley CV, Lee A. Prevalence of varicose veins and chronic venous insufficiency in men and women in the general population: Edinburgh Vein Study. J Epidemiol Community Health 1999; 53: 149–153.

[2]. Darke SG. The morphology of recurrent varicose veins. Eur J Vasc Surg. 1992;6:512–517.

[3]. Ravi R, Rodriguez-Lopez J, Trayler EA, Barrett DA, Ramaiah V, Deithrich EB. Endovenous ablation of incompetent saphenous veins: a large single-center experience. J Endovasc Therapy 2006;13:244–8

[4]. C-M Fan and R Rox-Anderson Endovenous laser ablation: mechanism of action Phlebology October 2008 23: 206-213, doi:10.1258/phleb.2008.008049