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Mini Review

New Generation of Intelligent Targeted Capsule Theranostic Robot System for Gastric Cancer

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Gastric cancer is the fifth most common malignancy in the world, and ranks third in both incidence and mortality of gastric cancer in China. The great challenge is that only 15% of early stomach cancer cases in China were diagnosed, the remain 85% cases were diagnosed at middle or advanced stages. How to realize precise diagnosis of early gastric cancer, and guide effective, safe and reasonable treatment, owns great clinical requirement. Facing actual requirement of theranostics of Gastric Cancer, our team has being developed next generation of intelligent targeted capsule theranostic robot system with the aim of reducing the mortality rate of gastric cancer patients and improve the public health level and quality of life.

We develop an intelligent targeted capsule theranostic robot system for theranostics of gastric cancer. The capsule in gastrointestinal tract is controlled by in vitro magnetic controlled device. The fluorescence signals generated by the multifunctional nanoprobes specifically binding H. pylori and early gastric cancer were collected in real time and transmitted to the in vitro receiving platform. Fast automatic analysis software based on artificial intelligence deep learning is developed to realize timely diagnosis of images. Combined with the light absorption and thermogenesis characteristics of the nanoprobes and the acoustic dynamics characteristics, the intelligent capsule diagnosis and treatment robot is developed to provide near infrared light source. Under the condition of energy provided by ultrasonic wave, the photothermal ablation and acoustic dynamics treatment of helicobacter pylori and early gastric cancer can be realized in vivo, and real-time imaging monitoring can be realized to judge the therapeutic effect. Wireless energy supply technology was used to solve the long-term energy supply problem of intelligent capsule theranostic robot; At the same time, the intelligent capsule theranostic robot was used to collect the gas produced by stomach lesions, and the mechanism of producing expiratory markers related to helicobacter pylori infection and early gastric cancer was studied.

The following 5 key technical problems are solved in this robot system:

1. In vitro precise control problem: how to realize the movement, turnover and stay of the gastric intelligent capsule theranostic robot in the stomach is a challenging problem. Although basic manipulation can be achieved using a permanent magnet combined with an external magnetic field, it is still a challenging technical problem to find the lesion, accurately focus it, image it in real time, and treat it. Through repeated tests, the technical conditions for the in vitro accurate control of the in vivo intelligent capsule theranostic robot with stronger control ability were established and solved the problem of in vitro accurate control.

2. Gastric near infrared fluorescence image excitation, information collection and real-time transmission: For integrating low-power near-infrared light source into the micro-capsule robot and using the near-infrared light source to stimulate specific targeted nanoprobes adsorbed on the

focus, the near-infrared fluorescence of higher band excited by the probes can be collected while avoiding the influence of emission light. It is realized to transmit images wirelessly to an in vitro imaging platform in real time to provide rapid analysis results and achieve targeted detection. The oral capsule robot developed by our team uses near infrared I and II light sources to irradiate gastric mucosa, and the current image acquisition and transmission technology is applied to solve the problem of near infrared fluorescence image were obtained and real-time transmission, and then were automatically analyzed.

3. Real-time image reception and intelligent automatic diagnosis: Through the establishment of a perfect image database, the establishment of a deep learning theoretical model, the use of large sample test results for matching training, can realize the automatic diagnosis results, the accuracy is significantly higher than manual interpretation. The solution of this problem lays the foundation for the development of intelligent capsule diagnosis and treatment robot.

4. Low power consumption design and wireless energy supply: By combining wireless energy supply technology, the energy supply problem of intelligent capsule theranostic robot in vivo is solved, which lays a foundation for the therapeutic application of intelligent targeted capsule diagnosis and treatment robot.

5. Safety of in vivo application: Medical plastic with high safety was adopted as the shell of the intelligent theranostic robot system to ensure the safety of use in the body and under the external magnetic control, it can be quickly and smoothly discharged from the body through the intestine. As for the oral theranostic nanoprobes, the safety of the in vivo application were evaluated. Through innovative design, the oral theranostic nanoprobes were not absorbed by the gastrointestinal tract and finally excreted through the intestinal tract.

Compared with the existing capsule endoscopy, the intelligent targeted capsule diagnosis and treatment robot system for stomach diseases developed by our team has the following characteristics: (1) Wireless energy supply, which can solve the problem of energy supply for prolonged gastric stay, specific lesion signal acquisition, photothermal, photodynamic and sonodynamic treatment and efficacy monitoring; (2) The low-power near-infrared light source is integrated into the micro-diagnosis and treatment robot, and through optical design, the micro-diagnosis and treatment robot can collect the near-infrared light of higher band emitted by the nano-probe excitation. The near-infrared light has stronger penetration and can improve the detection of gastric mucosal surface and submucosal lesions. (3) Real-time acquisition, transmission and automatic analysis of near-infrared fluorescence images, giving results, with the characteristics of artificial intelligence; (4) The micro-capsule diagnosis and treatment robot orally entered into the stomach is designed as a cylindrical structure. Two micro-near infrared light sources (near infrared I and II light sources) are used to expand the range of signal acquisition, avoid missing detection of local small lesions, and provide light sources required for treatment; (5) The gastric micro-diagnosis and treatment robot designed contains a module for collecting and storing gas and fluid in the gastric cavity, which is used to study the mechanism of gas components related to helicobacter pylori and early gastric cancer. (6) In vitro magnetic field control system supports patients to sit upright for examination, reflecting the humanization of the design; (7) Combining with the molecular image probe of stomach lesions, precise targeted imaging and positioning of stomach lesions can be realized, and the existing detection based on surface topography can be upgraded to the specific detection based on fluorescence, effectively improving the accuracy of stomach disease detection. At the same time, photothermal, photodynamic and sonodynamic treatment can be implemented according to the needs. This is the first time to develop this cross-direction gastric theranostic robot system, which has the characteristics of strong innovation.

The developed intelligent targeted capsule diagnosis and treatment robot can not only meet the needs of image diagnosis of stomach tumours and other diseases, but also meet the needs of therapeutic effect evaluation of stomach tumours and other diseases, and also meet the needs of basic research of stomach diseases. At present, the developed system is used to study the mechanism of producing gas components associated with Helicobacter pylori and early gastric cancer. In vivo observation of the process of specific nanoprobes targeting stomach lesions [48], combined with the Internet of Things technology, remote monitoring and diagnosis research was carried out.

In conclusion, the successful development of a new generation of intelligent targeted capsule diagnosis and treatment robot system has improved the independent design and innovative research capability of Chinese scientific instruments, not only forming a series of independent intellectual property rights, which can be transformed into high-end innovative instruments for the diagnosis and treatment of stomach diseases to meet clinical needs, but also breaking the pattern of relying on foreign imports of high-end medical instruments in China. Vigorously promote the development and clinical transformation of our high-end medical device industry.

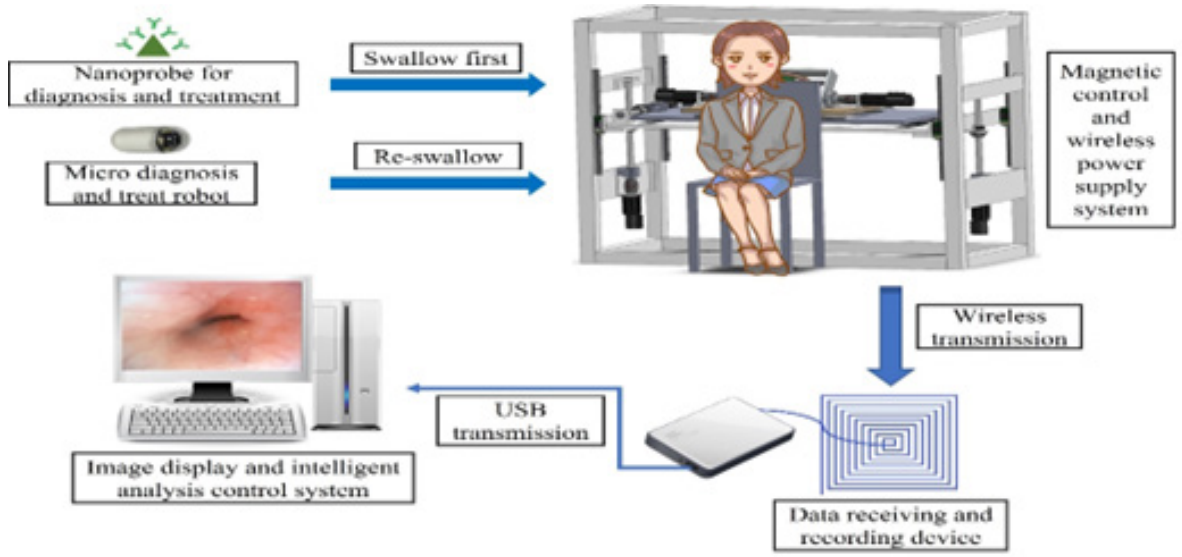

Figure 1: Intelligent Targeted Capsule Theranostic Robot System for gastric cancer.

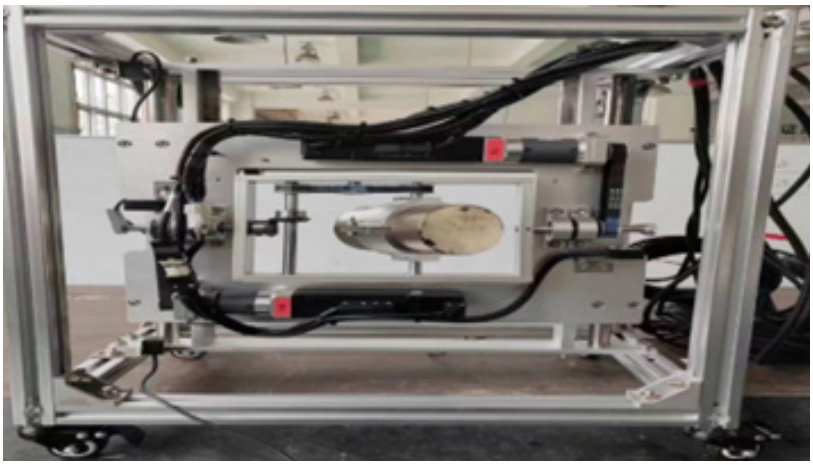

Figure 2: In vitro precise magnetic control device.

Acknowledgement

None.

Conflicts of Interest

No conflicts of interest.