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Original Paper

Feasibility Analysis of the Application of Automatic Intelligent Surgical Robots in Nasal Surgery

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Abstract

This paper discusses the feasibility of otolaryngology surgery to achieve automatic intelligent surgery from the current situation, professional characteristics, anatomical structure characteristics of head and neck, combined with the development of nasal endoscopy, minimally invasive surgical navigation, surgical robot technology and artificial intelligence.

Keywords

automatic, intelligent, surgery, robot, otorhinolaryngology, nasal department

Surgical robot is one of the most important areas in the field of medical robot. Surgical robot is a high-tech product integrating clinical medicine, biomechanics, mechanics, computer science, microelectronics and many other disciplines. It can complete surgical operations under the guidance of doctors through computer program control.

Today's otolaryngology surgery technology is developing from gross anatomical surgery to minimally invasive surgery represented by endoscope and microscope. However, in some high-risk anatomic areas adjacent to otolaryngology, such as skull base and eye structure, it is still quite difficult to carry out, and safer methods need to be found. With the development of computer artificial intelligence technology, computer intelligent navigation surgery system, also known as image navigation system, risen in response to the proper time and conditions. This system has been introduced into the field of otolaryngology, head and neck surgery in the past 20 years (Shu, Shen, Peng, et al., 2003). This technology can make current-time comparison between the actual position of surgical instruments during the operation and the preoperative CT and MRI images to help surgeons judge tumor boundaries,

protect adjacent important anatomical structures, reduce surgical invasiveness and surgical complications, and improve the success rate of surgery (Lyu, Sun, Chen, et al., 2004). The conventional operation field in the traditional nasal department is confined, inconvenient to operate, and the lighting equipment such as the forehead mirror or headlamp is not well lit, resulting in the shortcomings such as blurred visual field, poor visibility and operation blind area during the operation, which have many disadvantages to the operation of the surgeon and the learning of the students (Jiang & Hu, 2011). Since the implementation of nasal endoscopic surgery in the 1990s, problems of traditional surgeries such as narrow and unclear operating field, semi-blind operation, and serious injury of normal mucosa outside the operating area have been effectively solved, and the purpose of curing otolaryngology diseases by restoring physiological functions of the nasal cavity and sinuses can be realized according to the severity of the lesions (Huang & Wang, 1998). Good therapeutic effects have been achieved not only in the treatment of common nasal diseases such as sinusitis, nasal polyps and deviated nasal septum, but also in benign and malignant tumors of the nose (Garnier, Demougeot, Bertrand, et al., 2001; Endres, Fan, Hirt, et al., 2003; Bai, Gao, & Tan, 2011). However, the development of the combined surgical robot of nasal endoscope and surgical navigation system is still making slow progress, and the development of surgical robot is restricted by many factors at this stage. The feasibility analysis of intelligent automatic surgical robot of nasal department needs to consider many aspects, including technology, economy, law and ethics. On the one hand, from the technical point of view, the intelligent automatic surgical robot in the nasal department needs to have high-precision operation ability, stable control system, advanced image processing and analysis technology. In addition, it is also necessary to take into account the various situations that may arise during the operation and provide corresponding solutions. One the other hand, from the perspective of economy, the cost of intelligent automatic surgical robots in the nasal department is high, and it requires a lot of investment, researches and development expenses. At the same time, it is also necessary to consider the maintenance and renewal costs of the equipment, as well as the possible risk of surgical failure or complications. Moreover, from a legal point of view, the use of intelligent automatic surgical robots in the nasal department needs to comply with relevant laws, regulations and normative requirements to ensure that the rights and interests of patients are protected and to prevent infringement. Lastly, from an ethical point of view, the use of intelligent and fully automated surgical robots in the department of Rhinology needs to take into account the issue of informed consent of the patient, as well as issues such as human-computer interaction and moral hazard that may arise during surgery. To sum up, the feasibility of intelligent automatic surgical robots in nasal department needs to be fully studied and evaluated in technical, economic, legal and ethical aspects.

According to the author’s clinical experience in the nasal surgery, surgical robots can help doctors carry out more accurate surgical operations, reduce the surgical time and blood loss, and improve the success rate of surgeries. Therefore, the application of automatic intelligent surgical robot in nasal surgery is in a high possibility. In addition, compared with other anatomical parts of the operation, the application of

automatic intelligent robot operation has its own advantage in the ear, nose, throat, head and neck surgeries.

First of all, the operation of otolaryngology head and neck surgery is located in the nose and face, which has more bone and is relatively fixed, and the safety range of the nose and face is larger. Unlike brain surgery, the nerves are complicated, and the nerves are often hidden in the deep part of the nose and face surgery, some important risk prone and accident danger areas. Navigation technology can be used to locate dangerous areas and avoid surgical risks. However, most otolaryngology head and neck surgery is routine and involves fewer dangerous areas of the nose and face. Compared with other subspecialty operations in otolaryngology, head and neck surgery, nasal surgery has a greater safety factor, because nasal surgery has more bones and more cavities, and it is more advantageous to use a surgical robot with a flexible endoscope combined with nasal surgical instruments to perform nasal surgery. The flexible endoscopic surgical robot, which integrates suction, electrocoagulation, drilling, stripping and clamping, can complete almost all operations in the nasal department. For example, for nasal bone fracture, 3D CT and navigation system are used to locate the fracture site first, and the fracture reduction plan is designed. On the premise of accurate navigation and positioning, the nasal bone reduction device accurately reaches the fracture site, and the fracture site is fitted for stereoscopic, fixed-point and accurate reduction. This operation can also be combined with the endoscopic system to perform the operation under visual view. The deviated septum can also be combined with the navigation system to accurately design the surgical path, accurately reach the deviated site, and remove the deviated septum submucous bone. Sinusitis surgery, combined with navigation to accurately locate the sinus fenestration point, multifunctional endoscope soft mirror directly to the anchor point to open the sinus holes, exploration, suction, irrigation, all integrated to the operation, making sure the whole process is safe, effective and fast. Even with the help of the navigation system, we can have more confidence in the operation. In some situations of intraoperative bleeding, anatomic variation, and large-scale invasion of tumors, it can help the surgeon to correctly judge the local anatomical marks and the relationship with the surrounding tissue structure, sequentially improve the success rate of complex surgery (Lyu, Sun, Chen, et al., 2004). However, we should also consider that the image data of the navigation system comes from the preoperative scan and cannot reflect the intraoperative changes. During the operation, if the anatomical position is displaced due to partial resection of the lesion and cannot be displayed on the image in time, the information provided by the navigation will be inaccurate, and if the preoperative image navigation data is still relied on during the operation, the risk of surgery will be increased. For nasal surgery, due to the constant bone structure of the sinus and skull base, the skull base tumor will not be displaced just because of partial resection of the tumor during surgery. However, for large sella tumors or tumors that destroy skull base bone in a large extent and cause brain tissue compression and displacement, brain tissue retraction or intracranial pressure may easily cause displacement during surgical resection (Lyu, Sun, Chen, et al., 2004). In this case, Han, Zhou, Ge et al. (2001) pointed out that at this time, the navigation system should not be relied on alone,

but the observation under nasal endoscopy and the experience of the surgeon. In view of the guidance of experts, intelligent surgical robots can carry AI-assisted endoscopic probes to live up to intraoperative AI anatomical structure annotation, surgical navigation and surgical quality control, providing double guarantees for surgical safety. Nowadays, the technique of nasal endoscopic surgery is progressing rapidly and becoming more and more mature. Due to the good illumination and field of view of the nasal endoscopic system, nasal surgery has entered the era of precision and minimally invasive. Endoscopic nasal surgery has shown obvious advantages in terms of intraoperative positioning, postoperative response, and surgical operability (Yu, Wang, Xu, et al., 2022). The nasal minimally invasive surgical navigation system has also been launched in major hospitals, and the application of robotic systems in otorhinolaryngology and head and neck surgery is also in a stage of rapid development. Traditional oral and maxillofacial surgery is limited by narrow space, blurred visual field and more invasive operations, which often have a greater impact on function and beauty. The advantages of robot-assisted surgery in oral and maxillofacial surgery have attracted wide attention. The advantages of existing robotic surgery include the following: 1) The endoscope has high resolution and magnification, it can provide high-definition three-dimensional images; 2) With motion scaling and tremor filtering functions, it is allowed to do precise dissection and avoiding dangerous actions; 3) Surgical robot instruments are relatively flexible, and can enter small and complex spaces without or with only a small incision, avoiding more invasive operations. Single-arm flexible robots can perform minimally invasive operations on nasopharynx, oropharynx, larynx, larynx and other parts; 4) The use of retroaural or transoral robotic surgery can maintain laryngeal function without affecting prognosis, while reducing the impact on aesthetics; 5) The healing time of patients after robotic surgery is accelerated and the length of hospital stays is significantly shortened (Zhang & Li, 2021).

AI (artificial intelligence) technology is on the rise, and the research on automatic intelligent surgical robots has been carried out in medical institutions at home and abroad. Therefore, the integration of nasal endoscopy, minimally invasive surgical navigation, surgical robot technology and artificial intelligence can make the otolaryngology surgery achieve automatic intelligent surgery. It is believed that the arrival of the era of automatic intelligent surgical robots in nasal department is not far away.

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