Chapter

Introductory Chapter: Medical Robots in Surgery and Rehabilitation

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1. Introduction

After development of the first advanced robot, they have rapidly become a part of human life. Nowadays robots are smart enough to perform a task in factories, manage an operation in hospitals, and find their way in big shopping centers. The development in automaton and robotic technology are now inevitable. In every passing day, new inventions have been made, and people have come to such a point that they work together with a robot in an organization. Even they are doubtful for a future that a robot may take their jobs. Developments in automation made medical robots enter to several fields of medicine especially surgery and rehabilitation. In the near future, a robot may be a member of hospital staff. Compared to traditional methods, medical robots serve significant advantages to the patients such as better diagnostics, smaller incision, higher accuracy, lesser infection risk, shorter healing time, and longer lifetime.

The development of medical robots can shortly be examined considering three progressive generations, namely, the first-generation robots (like PUMA, Scara, and Delta), second-generation robots (like AESOP), and third-generation robots (like the da Vinci Surgical System). The first-generation robots have not been designed especially for medical purposes. They have been modified for performing medical tasks. The first operation was conducted in 1985 by using PUMA 560 robot manipulator which has a surgical arm mounted on its end effector. A successful neurosurgical biopsy was performed by this manipulator. This operation encourages the robotic experts to design new-generation robots for medicine. On the contrary with the first-generation robots, the second-generation medical robots have especially been designed for medical purposes. AESOP is in the second-generation medical robots. In 1990, AESOP produced by Computer Motion was the first robotic system approved by the Food and Drug Administration (FDA) for medical operations. The third-generation robotic manipulators have been designed and manufactured after the 2000s. These robotic manipulators like the da Vinci Surgical System have been developed especially executing challenging surgical and medical operations. Although the most challenging robots have been developed for surgery operations and people in the world interested mostly in these remarkable robotic systems, robotic rehabilitation devices have also been receiving increasing attention from both medical community and patients. In this chapter, the current status and designs of robotic systems in two major fields (surgery and rehabilitation) are going to be shortly described.

2. Medical robots in surgery

It may not be wrong to say that the most challenging robots have been developed for surgery operations since robotic surgery (also called as robotic-assisted surgery) includes many types of dangerous procedures that can be executed with full concentration. Robotic surgery is performed in a tiny incision, and the robot must be continuously under the control of the surgeon. In general, a robotic surgical system possesses arms equipped by camera and surgical instruments and a computer console near the surgical robot or operating table. The surgeon controls each arm of the surgical robotic system by using the computer console that provides surgeon many times magnified 3D view of the operation area. In conventional surgery, surgical operations sometimes take several hours, and the surgeon performs these operations at standing position. This makes the surgeon very tired and loses the surgeon's attention. On the other hand in robotic-assisted surgery, the surgeon sits on a chair and manages other medical staff in his or her chair during the surgical operation. This prevents losing the surgeon's attention to the operation. The other advantages of robotic-assisted surgery compared to the conventional surgical operation can be summarized as follows: smaller incision, lesser pain and blood loss, lesser infection risk, and shorter healing time.

One of the most important surgical robotic systems is without a doubt the da Vinci Surgical System that has been used in millions of operation since its first approval by FDA in 2000. Until now, the da Vinci Surgical System has been used in several different types of operations such as cardiac surgery, colorectal surgery, general surgery, gynecologic surgery, head and neck surgery, thoracic surgery, and urologic surgery [1]. While performing operations with the da Vinci Surgical System, the surgeon sits in front of a console and controls the four interactive robotic arms which are used for holding objects as well as act as scalpels (a little and very sharp-bladed instrument used especially for surgery operations), scissors, and graspers. The surgeon's hand movements are translated into small actions of the instruments mentioned above inside the patient's body. One of the robotic arms holds a camera and a light source which guide the surgeon during the surgery. When the surgeon moves away his head from the console, the activities of da Vinci Surgical System suddenly are stopped. Therefore any severe problem in surgery operation is prevented. da Vinci Surgical System has also some other safety features found in [2].

3. Medical robots in rehabilitation

Rehabilitation aims to help patients retain their lost abilities back and return their healthy daily life again. Robotic rehabilitation provides patents to perform some specific exercises to gain abilities back. Rehabilitation robots are especially used for assisting different types of sensorimotor functions like arms, hands, and legs. It has been shown that patients become familiar of rehabilitation robots day by day as the technology offers better opportunities and advanced rehabilitation robotic systems. Robotic rehabilitation can be classified in two major sections, namely, upper extremity rehabilitation and lower extremity rehabilitation. There are several types of robotic systems designed and manufactured for both upper and lower extremity rehabilitation.

3.1 Upper extremity robotic rehabilitation devices

The motor functions in upper extremity parts (shoulder, elbow, or writs) can be lost from several types of events such as sports injuries, trauma, occupational injuries [3–5], cerebral palsy in childhood, and stroke in adulthood [6]. This impairment in upper extremity deteriorates the patient's life in many ways such as socially and economically. Therefore it is very important for patients to recover their motor functions and return to their daily life as fast as possible. The number of patients damaged from upper extremity parts is quite high. On the other hand, the number of rehabilitation therapists at the hospitals is very low at present. Therefore it is not possible for rehabilitation therapists to heal all of these patients at current situation. One more difficulty for the patients is that rehabilitation therapies are quite expensive; therefore, it is very difficult to afford. Robotic rehabilitation devices are the potential candidates to recover all of the patient's lost motor functions although they are not extensively commercial at present in the world. It may be said that the manufacturing of more and cheaper robotic rehabilitation devices is a necessity to serve all the patients.

Upper extremity robotic rehabilitation devices have been started to be developed in the beginning of the 1990s [7]. Several upper extremity robotic rehabilitation devices have been designed since the 1990s. Some important points taken into account while designing robotic rehabilitation devices can be summarized as cheap, low mass, compactness, safe operation, easy wearing, portability, and home use [8]. Some recent upper extremity robotic rehabilitation devices can be described as follows: Mit-Manus [9], Reharob [10], Armin [11], Caden-7 [12], Medarm [13], Esa human arm exoskeleton [14], L-exos [15], Armor [16], and Sarcos Master Arm [17]. As can be seen from above studies, several upper extremity robotic rehabilitation devices have been developed as prototypes in general. The number of commercialized robotic rehabilitation devices is still very low compared to the number of patients.

3.2 Lower extremity robotic rehabilitation devices

Lower extremity robotic rehabilitation devices can be classified as treadmill gait trainers, footplate-based gait trainers, overground gait trainers, stationary gait and ankle trainers, and active foot orthoses trainers [18]. Diaz et al. [18] summarize the principles of the rehabilitation methods mentioned above in detail.

There are several lower extremity robotic rehabilitation devices that have been built until now. Some of them can be listed as follows: Alex [19], Altraco [20], Arthur [21], LokoHelp [22], Lokomat [23], Lopez [24], ReoAmbulator [25], and String-Man [26]. Although there are several lower extremity robotic rehabilitation devices developed as prototypes or for scientific research purposes, only Lokohelp [22], Lokomat [23], and ReoAmbulator [25] have been commercialized. One of the well-known commercialized lower extremity robotic rehabilitation devices LokoHelp is an electromechanical gait device and trains neurological patients with impaired walking ability [22]. LokoHelp has been tested in several training sessions, and results illustrate that LokoHelp as a robotics rehabilitation system is feasible in severely affected people having brain injury, stroke, and spinal cord injury [22].

The other well-known robot-assisted gait trainer Lokomat composes of a treadmill, a body weight support system, and a robotic gate orthosis. It helps severely impaired neurological patients. The studies illustrates that Lokomat provides effective training and high percentages of recovery potential [23]. The last commercialized lower extremity robotic rehabilitation device is ReoAmbulator that is also a body weight-supported treadmill robotic system [25].

4. Conclusion

In this chapter, the designs and current status of medical robots developed for surgery and lower and upper limb rehabilitation have been described. Although the history of both surgical and rehabilitation robotic systems are very short, hundreds of thousands of people have been treated by these robotic systems. The present state of especially surgical robotics amazes both the medical society and the patients. On the other hand, patients become familiar of rehabilitation robots as the technology presents better opportunities like cheaper and more useful designs. Every year new robotic designs for both surgical and rehabilitation purposes are developed for individuals from children to elderly people. As a last word, it is worthy to follow up the new designs and approaches on surgical and rehabilitation robots in the future.

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