Rama Med J 2014; 37: 48-51

Special Article/บทความพิเศษ

The Future Coming of Neurosurgical Robots

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In modern neurosurgery, the limitations to carry out the neurosurgical procedures based on conventional techniques were achieved already by neurosurgeons. The capability of 3 D imagination in neurosurgeons' brain and mind had be trained and practiced with experienced skill from generation to generation. This is very important skill for neurosurgeons to create the trajectory for their approaches under preoperative plan imaging. However technological improvements in image guidance and intraoperative imaging have become impact to the experienced human neurosurgeons. To perform the repeatability and accurate neurosurgical procedures is increasingly required even for the very tiny intracranial lesions or in the eloquent area in the brain or spinal cord. Also more magnification and minimally invasive means has enhanced the experienced human neurosurgeons to achieve and feasible to perform the ever impossible tasks before. Improvements and advent of computer technology, engineering, and minimally invasive surgery provided and created the concept of neurosurgical robot to assist neurosurgeons to carry out new trends of neurosurgical operations particularly the minimally invasive neurosurgery. Robotic surgery was introduced to the neurosurgery to accomplish a result with very high precision, accuracy and repeatability. To focus and operate inside the brain or spinal cord with very meticulous movement is needed in neurosurgical field. Accurate landmarks of the cranial or spinal anatomy have to be defined yet preoperatively and perioperatively to prevent brain or spinal cord damage. The beginning of robot assistance not replaces neurosurgeons but allowable neurosurgeon to perform the neurosurgical procedures with high accuracy and precision at the microscopic stage. There was a first report about the application of a robot in neurosurgery since 1985[1-3]. The use of Programmable Universal Machine for Assembly or PUMA for holding and doing biopsy in neurosurgical operation was proposed since then[3,4]. The applications of PUMA as a retractor in thalamic astrocytomas resection were reported[1,2]. However the appropriate safety concern was not mentioned consequently no acceptance in neurosurgical practice was cited clinically. The study stated the experimentation about NeuroMate was presented by Benabid[1,5]. It was used for assisting in the preoperative planning with imaging data to establish robotic position and conducted as a passive arm to carry out the neurosurgical procedures. After that, around 1000 cases were operated by NeuroMate system and reported[2-4,6,7]. Accordingly, neurosurgeons could not always know or organize the needle tip placement under image-guidance so it was unable to

monitor or define the position of the tool safely despite in brain shift condition during performing the operation. So a real-time image-guided arrangement was extremely needed to monitor and coordinated the position and orientation for neurosurgeon. As a result, Minerva was developed[3,6,8,9]. This system included a robotic arm installed inside a computed tomography apparatus to allow neurosurgeons to manipulate during the operation. A real-time to create or alter appropriate adjustments of the trajectory by neurosurgeons required was practicable. The magnetic resonance (MR) compatible robotic systems were rapidly followed. The advances of this system were driven by the investigators from several centers to build up their own MR-compatible robotic systems including in Asia, the US and Canada[10-12]. Early neurosurgical robotic systems carried out mostly of stereotactic procedures[4,5,13]. The Robot-Assisted Microsurgery System (RAMS) and the Steady Hand had been developed for improving the application of tool manipulation. RAMS was developed by the US National Aeronautics and Space Administration (NASA) to provide dexterity and increased precision during the surgery[2,3,6]. Based on master-slave control, the system was designed with six degrees of freedom and linked to a haptic hand controller. A feasibility study of RAMS was reported in microvascular anastomosis surgery[14]. Regarding Steady Hand system; which developed at Johns Hopkins University, is another robotic system to enhance neurosurgical microsurgery with eliminating neurosurgeons' tremor. However, the system has not been used commonly in clinical practice. A robot for telecontrolled micromanipulator in the course of the endoscope was developed[15,16]. NeuRobot is the robot characterized as a 10-mm endoscope with double tissue forceps, camera, light source, and laser was presented in clinical application[15,16]. Recently, the prototype of neurosurgical robotic systems used for spinal applications was introduced since 2007 with US FDA approval [17]. By Mazor Surgical Technologies, Renaissance was the authorization to exercise in spinal surgery. The robot is designed to be manipulated directly to the patient's spine. It is used to act as a guidance tool to position the target in the spine, define the trajectory and assist implant placement. It includes software for image guidance and be able to perform minimally invasive spinal surgery procedures[18-24]. It also has cranial applications for carrying out the minimally invasive brain surgery including brain biopsy or stereotactic brain surgery but it is still an ongoing study. Finally, engineering and technological developments in signal and imaging system for real time guidance for intraoperative monitoring, and minimally invasive surgery have pushed neurosurgeons beyond their capability limits and dexterity. The introduction of robotic assistance in neurosurgery has provided neurosurgeons improving their dexterities, minimal tissue traumatization, ergonomics, better visualization, accuracy, precision and repeatability to perform their procedures. The patient safety is paramount and concerned. The future direction of robotic assistance in neurosurgery will enhance the patient safety by providing accuracy, precision and repeatability in neurosurgical procedures and be the objective means to assess neurosurgeon performance.

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