Volume 5 / Issue 3-4 / 2010 - Features

Healthcare and Robotics: Miles to Go Before it Sleeps

Author:

Tosh Sheshabalaya
HIT

In spite of a variety of implementations since the 1980s, the field of healthcare robotics remains experimental and largely nascent. However, the long-term promise that it holds is acknowledged to be immense. This means that not only researchers and healthcare practitioners, but policy makers, too, are involved in bridging the gap between potential and reality.

Surgical Robots: The First Step

In the healthcare context, robots are now almost wholly used for surgical purposes. Various procedures from prosthetics (such as hip replacement) to a range of minimal invasive surgical interventions (especially prostatectomy, and other urological conditions such as bladder or kidney cancer) have been supported by robotics since the late 1990s.

The speed of acceptance seems impressive. According to Dr. Vipul Patel, Executive Director of the Orlando, Florida-based Society of Robotic Surgery: 85 percent of (prostatectomy) patients get their surgeries done robotically now. We would not have thought that possible a decade ago."

The bulk of robotic surgery is carried out in large university hospitals or specialised clinics. At one of the world's leading centres for robotic prostate cancer surgery, New York's Mount Sinai, a team led by the Head of its Minimally Invasive Surgery Department, Dr. David Samadi, has carried out over 3,000 interventions to date.

More recently, however, a growing number of smaller general hospitals are joining the robotic surgery roster, with a rapid growth in implementations. In the US, for example, Wheaton Franciscan Healthcare – Elmbrook Memorial, a Wisconsin-based healthcare facility, launched a robotic surgery offering in January 2010. By early July, it had already conducted 100 interventions.

Robots in Surgery: The Key Advantages

The key advantages of using robots for surgery are:

- Reliability: A lack of fatigue-induced errors, which are considered the bane of the surgical process. Minimally invasive surgeries are not called 'keyhole' for no reason. Some surgeons describe performing such procedures as driving a 40-tonne truck in reverse through a S-curve.
- Precision: The size of the human hand and fingers are an unavoidable physical limitation. Robots require smaller incisions and less room for manoeuvre.
- Effectiveness: Greater precision translates into smaller scars and quicker recovery, which in turn, means reduced hospital stay.
- Cost: Even in typical one-day, 'drive through' surgical procedures, the cost savings of a few hours (through the use of robots) can be impressive when aggregated across a large patient pool across a year. For Stanford University's Dr. Catherine Mohr: "Keeping a post-surgical patient who had an uncomplicated surgery in a bed in a hospital while they recover from that surgery costs that hospital 1,500 dollars per day on average; patients who have [minimally invasive] surgery go home two-and-a-half days earlier on average than patients having the same surgery through an open incision. The savings from being able to discharge patients earlier not only wipes out the premium cost for the robot instruments and maintenance, but actually brings the hospital out about 500 dollars per procedure ahead. The second big saving comes from a reduction in complications, which can cost a hospital up to three times what it will be reimbursed for a procedure, and associated blood transfusions, she adds.

Synergising Other Technologies

In recent months, research ers have been augmenting the effectiveness of robotic surgery by adding in a series of other technology innovations. In August 2010, for example, New York-Presbyterian Hospital/Columbia University Medical Center surgeons announced that using CO_2 laser for robotic prostate cancer surgery showed promise in reducing some of the major side effects of the latter (including long-term incontinence and sexual dysfunction in half of the patients).

Also, just a month previously, the Food and Drug Administration approved the use of robotics for treating obstructive sleep apnoea by the removal of lingual tonsils. Traditional (human) surgical excisions of the tonsils in adults to treat apnoea have been accompanied by a high degree of failure (re-growth), while systems such as continuous positive airway pressure (CPAP) machines remain associated with unacceptable impact on quality of life. One patient described it as ‘trying to breathe like a dog with its head hanging out of an open car window on a motorway’.

Going Global

A large share of surgical robotic activity is accounted for by the US and Europe, but new applications are rapidly growing in other parts of the world, too.

In Australia, Flinders Hospitals recently announced that 16 patients with abnormal heart rhythm have been treated via remote control surgery. Another 80 are due to soon join the list. Israel’s Mazor Surgical has made dramatic inroads in the US with a robotic system for spinal surgery, and plans to expand into Europe in the near future. It also seeks to get its system approved for brain surgery by the end of this year.

In August, the UAE and Qatar announced a list of their first surgeons authorised to conduct robotic surgery.

The Situation in Europe

Down the horizon is an inevitable increase in the spectrum of applications for healthcare robotics, galvanised by synergies and cross-fertilisation with other fast-emerging (and in some cases, related) disciplines, such as nano-technology and artificial intelligence.

Europe is clearly determined to be on the frontlines in this field. In 2007-2008, an EU Commission-sponsored expert group (led by TNO of the Netherlands) entered into consultations with experts and stakeholders. The group zeroed in on six representative areas as “ripe for further investigation and roadmapping” to stimulate market take-up.

Other than the core field of robotic surgery, dominated by American company Intuitive Surgical and its DaVinci robot, the other five go deeper into enabling technologies (robotised motor coordination analysis and therapy and intelligent prosthetics) and into a wider range of applications (smart medical capsules, robotised patient monitoring systems and robot-assisted cognitive and social therapy).

Best-of-class examples of each of the above five, which were highlighted by the EU initiative are as follows:

Robotised Motor Coordination Analysis and Therapy

This is designed to target patients with traumatised motor control (e.g. after a stroke, spinal cord injury, multiple sclerosis or Parkinson’s disease). It provides robotised analysis of motion and supports physical therapists.

A leading company in this field is Switzerland’s Hocoma, founded in 1996, and working closely with hospitals and clinics in Europe, the US and Singapore. Its core Lokomat System, launched in 2001, was the world’s first driven gait orthosis, and has been used for robotic treadmill training of neurological patients. A paediatric derivative, targeted at children (e.g. with cerebral palsy), was launched in 2005.

Another Hocoma robotic product is the Erigo, a pioneering tilt table with an integrated robotic stepping system. In late 2006, Hocoma launched the Andago, a new user-friendly system for manually assisted treadmill training.

The research focus is personalised therapy through user recognition as well as virtual reality (VR) and haptic feedback.

Intelligent Prosthetics

The EU study showcased a hand prosthesis from Germany’s Otto Bock which permits individual movement of fingers controlled by nerve signals. Additional systems (will) facilitate natural movement and intuitive control of arm and leg prostheses, with the same sub-conscious control as for natural limbs. Future research aims at brain autonomy and control by a patient’s peripheral nervous system.

More recently, however, an exciting new development from Britain shows the extent of latent potential in Europe in such fields. Shadow Robot is a small London start-up credited by two of the world’s toughest customers, US space agency NASA and the British Ministry of Defence, for developing the world's most dexterous robotic hands. While the Americans do not say what they wish to use it for the British Defence Ministry is ostensibly using the robotic hand for defusing bombs. Shadow Robot's hand is unique in terms of its lifelike nature. Its joints comprise 24 different angles of independent movement, and are powered by tiny tubular air pumped 'muscles'. Other than healthcare (and defence), the company's owner is also considering opportunities in the nuclear power industry.

Smart Medical Capsules

This NextGen system offers a way to 'journey' through the body of a patient with less discomfort than traditional (invasive) endoscopy. The smart endoscope is a 'pill' which is swallowed and then takes snapshots of internal systems such as the intestines. A robotising of capsules boosts their diagnostic effectiveness. In future, such capsules will also be introduced into the circulatory systems, thus boosting their relevance far beyond the digestive tract.

They could also be used to deliver medication (or radiation), directly where it is needed, and in patient-specific doses, thus signifying one of the most radical breakthroughs in medicine towards what has been billed as the era of i-Health.

Research in this area focuses on miniaturisation of robots (and convergence with nano-technology – in terms of the so-called 'nanobot') and some amount of artificial intelligence (AI) to take decisions. The goal is to allow the robot to move from external steering to self-propulsion.

The EU study highlighted a Swiss IRIS (Institute of Robotics and Intelligent Systems) minirobot, which can be introduced into the eye to perform precision eye surgery under guidance of a surgeon.

Robotised Patient Monitoring Systems

Europe's Welfare State healthcare model pays a great deal of attention to the specific needs of an ageing population, in order to enhance round-the-clock care-giving.

Current-generation remote patient monitoring devices (including several EU-financed e-Health research projects) assist physicians and nurses to look after patients staying at home. However, when unusual or emergency situations are detected, it is often a tough call to make a judgment call from a distance. Robotised systems, such as the Care-o-bot (from Germany's Fraunhofer Institute) aim to both enhance routine communications with an increased degree of efficiency as well as identify potential emergency situations.

However, the technical/legal challenges of such systems still remain huge. In the US, the FDA has cleared only one company to offer remote presence robot services to hospitals so far.

Robot-Assisted Cognitive and Social Therapy

The European Welfare State healthcare model goes at-home care-giving for the elderly (e.g. in terms of the robotised patient monitoring systems discussed above) to offer therapeutic functionality and develop or maintain social skills which are threatened by their relative isolation. An immediate associated benefit of such systems is their applicability to children – for developing basic social skills by play. Robotic systems can be programmed to generate a near-full range communicative sensory feedback (in terms of sound and colour as well as mimicking facial expression), provide incentives for movement (not least through the playing of games) and adapt to an individual person.

The EU study showcased CASPAR, a robotic system developed by the University of Hertfordshire in the United Kingdom, and designed to induce therapeutic play for children with autism.

The inherent entertainment/edutainment implications of such systems mean the presence of several competitors and contenders in this field – not least from the Far East (such as Fujitsu's 'enon' service robot and Mitsubishi's Wakamaru). In the US, GeckoSystems' CareBot is a mobile robot targeted at assistive home care for the elderly and their families.

The IT Challenge

Healthcare robots, like other medical machinery, are made of plastics and steel, aluminium and titanium, wires and flywheels, sensors and integrated circuits. The intensity of IT, however, is huge. Several healthcare robots have more software lines of code than an MRI.

Key systems in a healthcare robot include 2D and 3D medical image acquisition and analysis coupled to feature recognition algorithms (for example, to differentiate diseased from healthy tissue), micro-mobility and ultra-sensitive manoeuvring technologies, high-tech speech recognition, as well as continuous self-learning and artificial intelligence programs.

The American firm GeckoSystems has given a description of its CareBot, which it describes as “an internet appliance that is accessible for remote video/audio monitoring and telepresence.”

The physical structure consists of “an aluminium frame, plastic shroud, two independently driven wheels, multiple sensor systems, microprocessors and several onboard computers connected in a local area network. The microprocessors directly interact with the sensor systems and transmit data to the onboard computers.”

The onboard computers each run independent, highly specialised cooperative/subsumptive artificial intelligence (AI) software programmes (known as GeckoSavants™), which interact to complete tasks in a timely, intelligent and common sense manner.

Examples of GeckoSavants include GeckoNav™, GeckoChat and GeckoTrak™.

GeckoNav is responsible for manoeuvring, avoiding dynamic and/or static obstacles, seeking waypoints and patrolling.

GeckoChat is responsible for interaction with the care-receiver such as answering questions, assisting with daily routines and reminders, and responding to other verbal commands.

GeckoTrak enables the CareBot to maintain proximity to the care-receiver using sensor fusion.

Haptic Feedback

One major challenge for healthcare IT professionals involved with robotics is to develop more sophisticated haptic feedback (a perceptional sense of touch and grip control).

In spite of its acknowledged state-of-the-art technology, market leader Intuitive Surgical’s da Vinci system lacks such feedback for a surgeon. This leads to maximal compressive force by the robotic needle driver, during every grasping manoeuvre. As a result, repetitive robotic needle manipulation risks damage to fine sutures used during delicate procedures.

At present, human trials are due to begin with force sensors coupled to grippers and retractors, which aim to avoid gripping blood vessels too tightly. Other laboratory-scale developments include robotic arms which can flex and glide down pathways inside the human body without causing discomfort or scarring.

Health Tech Giants, Others Target Robotics

Major healthcare technology firms have begun targeting the robotics opportunity. In April, Intel and GE announced a USD 250 million joint venture to develop home medical monitoring technologies. After extending its Telepresence videoconferencing platform to Healthpresence (to enable doctor-patient) interactions, Cisco is reported to be considering application of the technology to surgical robotics.

So too have military technology firms. The Shadow Robot referred to previously demonstrated the convergence between military and healthcare robotics applications. A similar synergy is shown in Dr. Catherine Moor of Stanford University (who is also Director of Medical Research at Intuitive Surgical –vendor of the DaVinci surgical robot): she began her career designing high-altitude aircrafts.

According to Healthcare Information Technology Management sources, a commercial spin-off from the military shortly due to hit the market is a head-up display (HUD) interface for a surgical robot to overlay CT scans upon the organ in question.

The Next Frontier: Artificial Intelligence

Researchers at Duke University in the US are studying equipping surgical robots with artificial intelligence to perform routine medical procedures.

One of the first human trials slated to commence within three – five years involves needle biopsies, a commonplace tool used to diagnose cancer. Researchers at the University, led by Prof. Stephen Smith, believe that existing computer 3D imaging technology combined with robotic artificial intelligence (AI) may soon free valuable time on the part of physicians performing this routine procedure. In simulations with animals, he states, the robotic AI system has shown the ability to locate the centre of a tumour and accurately insert the needle within a space of two millimetres. More recently, the Duke researchers have begun adapting the system to obtain evenly spaced samples across the entire tissue. The entire procedure currently takes one minute to complete.

However, with more sophisticated robots and faster computer programs, Prof. Smith says that the time required would be reduced to seconds.

Other applications of AI-assisted surgical robotics look set to also follow during the current decade.

Legal Pitfalls of Robotic Surgery

HITM Analysis

In spite of the promise and excitement surrounding robotic surgery (as well as the wider use of robots as health caregivers), one of the most vexing issues is the legal framework within which hospitals begin to deploy robots.

Robotic surgery, in particular, will demand an exceptionally high level of training for overseeing physicians. The immediate challenge in this respect consists of the learning curve - the process of acquiring experience, and sufficient amounts of it, in order to impart the training. Alongside this would be the task of composing a credible certification body to give legal recognition to such experience, and assessing issues of professional liability. Who will such an organisation consist of – unless there are enough experts to staff it ? Future experts will, after all, be undergoing training, for a certain period of time, as demand is likely to comfortably outstrip supply.

It is also unlikely that a peer-group structure, composed of experts who sit on the certification body part of the time, and then perform robotic surgery afterwards, can withstand the pressure of conflicts of interest. As a former US presidential contender may have said: ‘It is a surgical process, stupid, not a highbrow research paper’.

The issue of liability will inevitably pose its own set of trials and tribulations.

While the legal basis for physician liability is likely to remain similar to conventional surgery, a negative outcome in robotic surgery would open the floodgates to not only sue a physician and hospital, but also the vendor of the robotic system.

Litigation after remote robotic surgery would be additionally painful. Apart from physicians, hospitals and robotic system vendors, patients could also think about suing the telecommunications company.

The next question would be one most lawyers are familiar with – that of extraterritoriality. Whose laws would be used if the remote robotic cybersurgery is performed by a physician on a patient in another country, using undersea fibre optic cables owned by a company in a third?

Under such circumstances, the verdict is clear.Robotic surgery will take off slowly, very slowly, beginning with tightly- controlled pilots and trials in a few hospitals.Even as training programs mushroom for robotic surgeons, we can safely expect a flood of applicants for courses in robotic malpractice laws. Our litigation-happy American friends may indeed be already on the job.

Published on : Wed, 15 Dec 2010