

The role of robotics in interventional radiology: current status

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Introduction

The evolution of medicine has moved from open procedures and non-targeted medications to minimally invasive therapies to treat complex problems with even more accuracy. Therefore clinicians choosing a career in interventional radiology are engraining themselves in the exciting future developments presented to the speciality. On the diagnostic radiology front multimodality fusion and functional imaging promises to further improve the capability of the radiologist to diagnose problems down to a molecular level and this dominates the health news pages related to the field. In interventional radiology the next big step to try and improve accuracy of targeted procedures is the introduction of robotics. One of the key note talks at the British Society of Interventional Radiology annual meeting 2014 was specifically related to this topic (1). In addition this was a topic discussed at TEDMED UK 2013 and highlighted that radiology can overcome some of the problems that have been encountered by surgical robots (2).

A robot is “*a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or other specialised devices through various programmed motions for the performance of a variety of tasks*” (3). Robots have long been used in the industrial sector and were first adopted in the mainstream by the General Motors Company in 1958. Robots have been used in various areas of medicine with the surgical application being very much at the forefront of its use in clinical practice (4).

The first medical robot used was ROBODOC. This was an automatic drilling robot that inserted implants in orthopaedic arthroplasty (5). This was released in 1992 and obtained Food and Drug Administration (FDA) approval

as a fully automated robot in 2008. Laparoscopic surgery has been another area where robotics has developed. The most prominent of these is the Da Vinci surgical robot system developed by Frederick Moll. With this system the surgeon uses a remote receiver to manipulate the robot arms and therefore the surgical instruments (6,7). In 2011 worldwide in excess of 100,000 prostatectomies and 125,000 hysterectomies were carried out using robotic systems (8). This editorial explores the current and potential uses of robotics within interventional radiology.

Why does interventional radiology need robotics?

It is generally thought that the interventional radiologist can already enter cavities precisely in nearly every area of the body in a minimally invasive way. Therefore why is a robot required? There are advantages to implementation of the robot. Firstly learning to manipulate a robot to complete complex interventional procedures means that the radiologist can be remote to the suite where the procedure is being carried out and therefore does not receive any radiation exposure. Secondly the robotic instruments have been designed with several degrees of freedom in navigation making their dexterity better than the average human being. This means that in patients with complex anatomy, navigation of the interventional devices would be easier and therefore safer. Thirdly the newest robotic instruments are magnetic enabled, making magnetic resonance imaging (MRI) guided interventions faster and more accurate. This is extremely exciting as MRI guided intervention can offer instant feedback on treatments with real-time functional parameters. One of the biggest challenges in surgical

robotics entering cavities is the need for a stable power supply combined with being wireless. Research is being carried out to assess how wireless power supplies can be maintained via the use of the MR scanner (2).

Robotic CT and MRI guided procedures

Computed tomography (CT) and MRI have been the obvious first areas for robotic guided interventions as they both offer three dimensional imaging of any area of the body in fairly high resolutions. CT guided interventions are well established but the disadvantages of radiation exposure, constrained tunnel dimensions, multiple steps to position the needle and planning occurring outside the scan room mean that procedures can take long periods of time. MR guided interventions are less well established due to the cost, tunnels sizes and constraints on instruments that can be used (9).

State of the art robotic instruments that are patient mounted or table mounted can overcome many of the challenges described with the advantage of increased accuracy and efficiency. An example of a robot that is MRI and CT compatible is the Light Puncture Robot being developed in Grenoble, France. Preliminary robotic CT and MRI procedures focus of percutaneous biopsies, radiofrequency and cryoablation (10). The added advantage of real-time three dimensional functional imaging with MRI means that future robotic interventional suites may contain a hybrid CT and MRI scanner. MRI guided interventions can offer instant feedback of the efficacy of the therapies with functional parameters from the scanner such as blood flow, tissue temperature and tissue oxygenation (11).

Robot ultrasound guided procedures

Two dimensions ultrasound imaging is very operator dependent therefore the development of robots in this area has been slower to develop. However there is research to show that if a predetermined trajectory is identified and position of the ultrasound probe is stabilised, robots can maneuver needles into a predetermined trajectory with the use of tissue motion analysers (12). Transrectal ultrasound (TRUS) is already being used in combination with the Da Vinci robot for prostatectomy. The TRUS allows visualisation of the instrument tips, dissection planes, bladder neck and neurovascular bundle all with the aim of reducing complications (13). Currently ultrasound is used as an adjunct to surgical robots rather than as part of interventional radiology.

An alternative use of robotics in ultrasound is to enable telerobotic systems to provide diagnostic ultrasound to areas where there is no local available radiologist or sonographer. I practitioner can remotely control the position of the probe on a patient to produce sonographic images that are immediately visible to the practitioner controlling the robot anywhere in the world (14).

Robot fluoroscopy guided procedures

Biplanar fluoroscopy is not as well adapted for robotic procedures as CT and MRI due to its two dimensional nature. The AcuBot is a robot that can accommodate fluoroscopic interventions and has demonstrated good accuracy for perispinal nerve and facet joint injections (15). However the mainstay of fluoroscopic robotic procedures in the future will be related to endovascular procedures which are explained in the next section.

Robotic endovascular procedures

The use of robotic catheter steering systems were used initially in catheter placement in cardiac ablations and were further adapted to percutaneous coronary intervention (PCI). Potential benefits to patients include accurate lesion calculations, precise stent placement, and reduced radiation exposure and contrast delivery (16). This system has been adapted to peripheral vasculature. Riga *et al.* have developed the use of a robotic system from phantom and porcine model to human use for the insertion of fenestrated stent grafts in the renal artery. Their system additionally used a robotic arm for the cannulation. This technique has been used in limited clinical practice and found to have post interventional complications. Their findings showed the robotic system enabled precise manipulation, positioning, and minimum instrumentation of the vessel whilst minimizing operator radiation exposure. It was also noted that the robotic arm for cannulation reduces vessel cannulation times (17-19).

Endovascular robots actively steer the tips of catheters precisely using magnetic fields. The use of robots in vascular work can alleviate the limitations of the human being and could also significantly reduce the cost of endovascular interventions by alleviating the need for bespoke fenestrated stent grafts as in situ fenestrations can be created. As complex endovascular techniques are often long leading to lengthy exposure to radiation (20).

This early clinical experience suggests safe and

efficacious treatment for cardiac and aortic vascular disease and could potentially expand further peripherally. Further research that focuses on procedural improvement and integration with 'real-time' imaging techniques are required to determine the long-term value and effectiveness of these robotic assisted procedures, however robotic endovascular techniques have the potential to become the mainstay in vascular interventional radiography in the future.

Conclusions

The future of interventional radiology is combining the fusion imaging techniques that are rapidly emerging with the constant advances in robotic technologies. I hypothesise that with the correct training this will lead to an increase in the accuracy and efficacy of interventions with the added advantage of reduced radiation dose to the radiologist and physiological feedback on therapies. Robotic interventional radiology could become a subspecialty in itself and this will lead to the development of new procedures that are currently not available. The combination of rapidly advancing engineering systems, expert medical knowledge and evidence based research is always exciting. The next big challenge which will affect the speed at which interventional radiology robotics spreads is the ongoing financial strain that is facing health care systems worldwide. However training radiologists should have one eye on the future and should grasp opportunities to train and be involved in research related to this topic.

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