Remote assisted endovascular / simulation

Introduction:
Over the last decade, there has been a rapid development of minimally invasive interventional techniques surrounding endovascular interventions. There are numerous advantages to using these techniques including faster recovery of the patient and shorter hospital stays. In this monograph we focus on various techniques for remote assisted endovascular medical applications and remote assisted endovascular simulation for physician training. The information herein was derived from the references listed at the end of this paper.

The Problem:
Endovascular procedures come with many challenges including the inability to access hard to reach anatomy and to maintain stability during the procedure. Second, endovascular procedures also require extensive physician training. Remote assisted endovascular devices for medical applications and simulation devices for physician training have relieved some of these challenges. With the rapid progression in high speed computation, endovascular procedures have become somewhat simplified. In addition, the advancement of computer hardware and software in these devices have made the task of gathering and illustrating image data for procedural training dramatically more user friendly.

Medical Applications:
The most common remote assisted endovascular applications involve magnetic tracking technology. These instruments allow for real-time position measurements of medical devices such as catheters and needles without sight restrictions. Current catheter tracking is performed using 2D fluoroscopy. This technique does have drawbacks such as overlap and foreshortening. Recently, an alternative to fluoroscopy-based tracking has been proposed. By means of a magnetic tracking system (MTS) the device's position and orientation is accumulated and then registered to a pre-operatively acquired image. This is in contrast to the conventional method of tracking the catheter, needle etc. The drawbacks that traditional methods contain are eliminated by using non-line-of-sight localization systems, such as the MTS, and measuring the device location in 3D space.

In order to carry out many endovascular interventions, a guide wire often needs to be manipulated with fluoroscopic guidance. This task is complicated by the fact that only projection images are obtainable and that these instruments are made to be handled by the tail end. The Hansen Medical Catheter Control System is one piece of equipment that has been developed to ease the process. This device uses computed catheter technology and fine guide catheter control in 3D to provide predictable movement. In addition, its one of a kind design allows the physician to easily move their workstation away from radiation exposure. This allows the physician the ability to more easily access the anatomy. By pairing robotic technology with computed movement, the Hansen Catheter Control System allows physicians to more easily control and maneuver catheters within the heart to treat disorders.

Stereotaxis is another company that has developed technology for remote assisted endovascular procedural applications. The Niobe System, as it is called, uses computer controlled magnets that are positioned external to the body. When activated, the magnets create magnetic fields around the patient. The clinician has the ability to programmatically maneuver the magnetic tipped catheters and guidewires throughout the endovascular system. A digital fluoroscopy system is used to visualize the devices as they are navigated. Like the Hansen CatheterControl System, the Niobe System allows the physician to be seated in a control room away from radiation exposure. This system allows for more rapid and precise routing of devices which allows the physician to focus more on the patient and less on the mechanics of the procedure. It is currently approved in the U.S. for endovascular mapping and is approved abroad for mapping and ablation.

Physician Training:
Recent literature describes the uses of computer simulation for determining endovascular skill levels in procedures such as carotid artery stenting. While it is quite possible that this practice will gain approval from the US Food and Drug Administration, many questions have been raised on how to train physicians in its application and its use in other procedures as well. Various simulators have been developed for this reason. The Vascular Intervention System Training (VIST) simulator is one such model. The VIST consists of a personal computer attached to a mechanical device that allows the user many actions such as the insertion and manipulation of wires, stents and various other devices. Tactile feedback as well as simulated visual images are provided to the user. Research suggests that the VIST and devices like it have an important role in training for carotid artery stenting.

The SimSuite Education System is perhaps one of the most advanced surgical simulators that exist on today's market. The overall goal of the system is to improve clinicians' skills on minimally invasive interventions. With this device, operators are able to perform clinical scenarios just as they would in an actual procedure. They have the ability to carry out pre-procedure evaluation and management, simulated intervention, and post-procedure care and management. The system uses real patient scenarios and images as well as true-to-life vascular anatomies. Clinicians are able to experience their own tactile sensitivity as in real procedures. With the ability to perform entire procedures from start to finish and repeat the process, if desired, this system provides advanced clinician training.

Illustration from http://www.medsimulation.com)

Many endovascular interventions require the use of a guide wire. The task of manipulating this device is complicated due to the fact that only projection images are obtainable. Simulation technologies have been developed to better train physicians in the use of guide wires. One problem with these simulators is that of deformable models. Such simulation needs to be based upon an algorithm that is both realistic and fast. Various techniques, each with their own problems, have been developed to simulate endovascular interventions. These include, but are not limited to, the finite element method, snakes and splines, mass-spring models and multibody dynamics. Recently, an analytical guide wire motion algorithm has been developed. The algorithm is highly generic being based on elementary physics and has been found to have good convergence properties. When compared with 3D rotational angiography data of a real guide wire, it was found that the new algorithm produced realistic results.

Computational replicas and their use in endovascular simulation have also been an important topic in recent research. Primarily, the texts present issues with these replicas that surround the treatment of vascular disease. In the past, researchers have used a wide variety of methods for imitating real aneurismal geometries. This list consists of tubes made of rigid glass, acrylic, or silicon rubber. Today, because of the advancements of computer technologies, the goal of creating a user-oriented computational system to map the individual patterns of the endovascular system has become more attainable. Older replicas require the user to be extremely well versed in computer methods as it is not easy for clinicians to implement their use if they do not possess this skill. New studies have sought to determine how 3D imaging data can be used to create numerical grids for simulation. The DICOM format is one such format that has been tested for use in this process. Studies have shown that this approach may very well promise to be a practical tool for widespread physician use. In conjunction, Simbionix has developed its second generation of technology for minimally invasive therapy training. They have provided the ability for physicians to obtain training in advanced endoscopic procedures. Additionally, Phantoms by Design has focused its manufacturing on custom phantoms for medical ultrasound and magnetic resonance imaging to help fight against cardiovascular disease. Recently, they have begun testing on its physiological pulsatile carotid and coronary artery flow phantoms for magnetic resonance imaging.

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Interview

- Phone interview with Paul Burmeister at Stereotaxis

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