Opinion

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Robotics in Arthroplasty

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ABSTRACT

Abbreviations: CNC: Computerized Numerical Control; CAD: Computer Aided Design; CAM: Computer Aided Manufacturing

Opinion

If one enters "robotics" and "joint replacement" in any search engine of the internet, an impressive number of links to very recent articles is presented [1-3]. Obviously, this is a current topic of high interest to - well - to whom -surgeons, industry, health care providers, patients? So, the question arises:" Are we on a threshold to a new area and if so - how could that look like?" In order to better understand what is going on it is important to clarify a few things and look into the history. As for the clarification, the machines that are currently presented for the use in joint replacement are devices that are in their most elaborate version, the MAKO system (STRYKER, Kalamazoo, MI, USA) Computerized Numerical Control (CNC) milling machines that follow a Computer Aided Design (CAD) plan which was transferred into a tool path by a Computer Aided Manufacturing (CAM) software. This is technology that every carpenter or mechanic is quite familiar with. It had been introduced in technical and industrial production some forty years ago. Due to regulations, surgical CNC machines are much more limited in what they are allowed to do and dependent to user guidance and interaction compared even their simplest counterparts in mechanical engineering. The sole task these devices help with, is getting the bone cuts right - which is an important part - but certainly not the only part of a joint replacement surgery.

The surgeon is not replaced by a robot, he just gets a little more sophisticated tool at hand. Soft tissue preparation and handling, performing releases remains in the surgeon's hands as well as all the fundamental decision making on what and how things have to be performed for the specific patient. The plan of what parts of bones need to be cut is made by the surgeon and based on his knowledge and experience. This is not any different from an engineer that buts all his knowledge into the CAD drawings of a technical part and uses a computer guided milling machine to cut it out of a bloc of metal, plastic or wood. Coincidentally I was involved in the transition of an industrial workshop from manual production to CAD-based computer aided manufacturing as and IT specialist more than thirty years ago. I had to convince technical "artist" who could "feel" a 0.1mm step in material with their thumb nail, that giving up a little bit of their artistry with hand held tools and replace it with the ability to plan what they wanted to design on a computer screen with high precision. The fear to lose their art, their manual abilities, their reputation was great and required a lot of discussion. And all these "artists" claimed that they could be as good as those machines or even better and react to the specifics of the material, room temperatures and other parameters much more effectively than any machine would ever be able to.

As we know now, all workshop that are still in business succeeded with this transition to CAM. Being able to draw a plan on a computer, calculate the machine path with a CAM software and have a CNC device executing the plan is standard knowledge of everybody in the business nowadays and the gold standard of production. A couple years later I started my surgical carrier in orthopedics and was stunned to see that everybody was doing such important cuts on a patients one and only left or right whatever

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bone with a only onetime change to get it right with the simplest tools imaginable. Eyeballing, using rods for directions inside and outside long bones, having pins defining directions and trying to manually line up saw plates with them - or having intraoperative C-arm shots helping to align jigs to some poorly defined landmarks was the best they had. This has not changed much until today. All has been done with handheld tools not any more sophisticated than what you get at home depot. Why would one not want to have the ability to plan whatever has to be done on a bone preoperatively and have devices that hand that guarantee that the preoperative plan is precisely executed in surgery? Obviously there are some obstacles in patients compared to a piece of metal, plastic or wood. The fundamental problem is that it is not possible to rigidly fix bones to and define a coordinate system for the machine. Bones have to be scanned as they are individual, and the plan based on this scan has to be matched with the bone in surgery.

Additionally, the bone's position has to be followed throughout the procedure as it is moving [4]. This matching and following is a huge problem and we are certainly not at the end of the development of solutions for it. Nevertheless, solutions are on the market and their principal ability to do what they need to do is not in doubt anymore. Navigation systems and robots have proven technology that works [3,5-8]. Let us look to financial aspect. Is this technology, although it is working, currently too expansive? Possibly. If every orthopaedic surgeon who currently does total joints would have to buy a robot at its current price the numbers won't work out. As always prices will come done as competitors enter the market. And yet, technology not only changes technical aspects of what we do, it typically changes the overall way how services are provided [3,9]. This is an effect that is well described in the economic literature and is relatively independent from the wishes of those who provide the services. If this technology shifts the focus from artistic execution to evidence based preoperative planning, expertise could be split between those who plan and those who execute and allow a more effective service provision. With this in mind one might envision the development of robot based joint replacement centers with very high-volume output, standardized implantations, high expertise in planning and a very effective surgical service.

The idea of joint replacement surgery as day surgery fits perfectly well into such a scenario. Let us take a small geographical region with a few hundred thousand inhabitants with 5 - 6 public hospitals in which all hospitals provide joint replacement services. Let us assume in this are 3000 total joints are done per year. How many surgeons do we need for that if we had one place that is focusing on the efficient provision of joint replacement services in a robotic environment with high planning expertise and precise execution of the plan. How many surgeons to we need for that if one surgeon would do 600 joints a year - we would only need five surgeons for the whole area, that is it. Would the rest the joint surgeon in the area be happy? Certainly not. Would the overall costs for the 3000 joints come down? Presumably. We can see this as a bright future or a horror scenario. We can fight this development or welcome and support it. With the introduction of almost industrial production processes into joint replacement through robotic I am absolutely convinced that the first steps in this direction are set. Like 30 years ago mechanical engineers, today we surgeons argue that we are artist, that we can do things better than any machine, that we can react to individual situations and needs .... Yet, there is no reason to believe, that we will do joint replacement as we are currently used to do it, forever - there will be changes, and we will have to adjust our ways to work, to live, to earn money and reputation. Let us be excited to see those changes take place and nor fear them.

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