ROUNDTABLE DISCUSSION
The Use of Robotics in Arthroplasty

ABSTRACT

The use of robotics in arthroplasty has increased in popularity in recent years. The purported benefits of this new technology include improved component placement and more consistent resections. However, there is some resistance to robotic utilization due both to cost and concerns that the added data may not result in improved patient outcomes. In this roundtable, we discuss the proposed benefits as well as the downsides to the use of robotics in arthroplasty.

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One or more authors have potential conicts of interest related to this work. The complete Disclosure of Potential Conicts of Interest submitted by the authors is available with the online version of the article.

Thank you for participating. Every year, the Orthopaedic Journal at Harvard Medical School hosts a roundtable on a topic of interest for our readers. This year, we decided to delve into the topic of robotics in arthroplasty.

We've been doing arthroplasty for a good number of years and have been fairly successful at it in general. What clinical problem *is being solved* by robotics?

DR. CHEN: Implant companies like to reference the fact there is 20% dissatisfaction with total knees which robotics may be able to solve. However, I don't believe the goal of robotics is to solve dissatisfaction. A robot is not performing the surgery; it is not overtaking our roles as surgeons. Robots are adjunct tools that can assist us with surgery. A robot serves as a saw or a guide by which you can put in a saw blade, and it can help us be more precise. For example, if I want to cut one more millimeter of distal femur to raise the joint line a little bit to help with the extension gap, I can do that with the robot. I can't do that with the naked eye, as all of our guides are 2mm. I think robots help with precision and improve our ability to use technology to better perform the procedures we already do.

DR. KWON: Studies demonstrate that surgeons view the role of robotics in terms of improving precision. It is analogous to using a GPS to drive to a destination. Using robotics helps eliminate a significant number of outliers; it is the proven benefit of robotic systems. This is still a work in progress, however, because while precision is increased, we still do not necessarily know what we should aim for in order to optimize patient outcomes. It is certainly the case with the hip applications. There is no doubt that using robotics will give you the precision in terms of implant position—particularly cup position. However, we do not currently know whether that is the optimal component position for a particular patient. The same can be said for total knee application. Should we aim for mechanical or kinematic alignment? There is currently limited evidence that robotics leads to significantly improved patient outcomes at this time.

DR. MELNIC: I think robotics may potentially help low volume arthroplasty surgeons. We know most arthroplasties are being performed by surgeons who are doing a low volume annually. When you're only doing 5, 10, or 15 cases a year, it increases your chances of seeing outliers. You then get into a discussion about whether surgeons who are only doing 20 cases a year would benefit from using a robot. I think a major benefit of robotics is helping those surgeons who don't do a lot of cases annually—to minimize their outliers.

We've discussed what robotics is doing for surgeons and a little about what it is doing for patients—even if we don't have that data yet. What do you see in the future as the evolution of robotic surgery? Do you see us translating these numbers to patient outcomes?

DR. MELNIC: This is what implant companies are trying to do. Currently, companies are trying to find a way to link intraoperative data with patient outcomes. This would allow them to link objective data in the operating room with subjective patient data.

DR. CHEN: I agree with Dr. Melnic. I really hope outcomes from robotic surgery are demonstrated in long-term outcomes. In theory, if you put in the knee in a radiographically appropriate position, the longevity of the prosthesis should be improved. It is possible that by making the knee more balanced, it could have less mid-flexion instability and less revisions in the long run or lead to less aseptic loosening. Eventually, we hope to not only have short-term or 5 year PROMs—but eventually—10, 20 and 30 year outcomes for robotic total knees, total hips, and partial knee replacements that demonstrate improvement with the use of robotic technology. Unfortunately, only time will tell us that!

What is the current resistance to implementation—besides resources (as some places don't have robots yet available)? What do you feel are the impediments to moving these tools into practice?

DR. CHEN: Back when I was working at Rothman, Dr. Rothman would always ask, when discussing robotics, "What problem are we fixing? I have been doing total knees for 30 years, and my knees are perfect." He was the staunchest advocate against robotic technology. Generally, one of the areas of resistance is high-volume surgeons who have done the same surgical procedure for many years. They're asking, "Why do we need to do it with a robot?" Established surgeons have good outcomes, and they understand using a robot will involve a learning curve. The procedure will take longer, and an open wound for a longer period of time could lead to an increased infection risk. Thus, adoption of robotic surgery from an older surgeon's perspective—or even a younger surgeon who did all of his/her training manually—is difficult for these reasons. Cost is also a very common concern for implementation. Finally, while most major companies now have robotic systems, historically, if a surgeon was accustomed to using a specific implant system, most did not want to switch implants and the system they were accustomed to using for the sake of using the robot.

"I don't believe the goal of robotics is to solve dissatisfaction. A robot is not performing the surgery; it is not overtaking our roles as surgeons."

DR. KWON: For a surgeon to change his or her standard of care or practice, the most important thing we usually look at is evidence of improved patient care. At this point in time, we don't have this evidence to support widespread use of robotics. I see this as one of the most important obstacles. Any sort of new technology has this issue. It has been suggested in the literature that the safest way to introduce a new technology is in a step-wise manner. You start with small inventor series studies, then build up evidence along the way—including multicenter studies—prior to widespread use for everyday surgeons. I don't think we currently have that in this setting.

Dr. Chen—you touched on this a little bit with your quote from Dr. Rothman—how much of this resistance is related to pride? You have discussed 1mm cuts and perfect total knees. Is it difficult as a human to be measured and have a third party say, for example, your cuts are always 3.4 degrees when you're going for 5? How much of this resistance is accepting some of the unknown of surgery and being comfortable with that?

DR. CHEN: There is still a good deal of unknown involved in surgery. With robotics, the challenge of having too much data can actually be frightening. When I put in my trial components and look at the final robotic numbers—to Dr. Kwon's point—is it acceptable? The computer can say there is a 5 degree flexion contracture, but when I look at the knee, it looks completely straight. If I were performing a manual TKA case, I would use my visual cues 100% of the time. However, if the robot tells me there is a 5 degree flexion contracture, how do I use that information? Do I cut more distal femur? Do I change my cuts to match the computer and risk hyperextension? This is where it is vital to know how to do the surgical procedure first, without the robot, and being comfortable with those outcomes before doing all cases robotically. The fundamentals are still the most important. To Dr. Melnic's point, is important that surgeons need to know how to do these cases manually first, and if they have too low of a volume, then robots can be helpful tools.

DR. MELNIC: Currently, we don't truly know what to do with all of the data. We see surgeons who put in their knees very, very loose and we see surgeons who put in their knees very tight. We see master surgeons who do both and have great outcomes. The problem is that we just don't know what to do with the numbers.

When the robot makes a mistake, who is responsible for that mistake? How do you foresee these conversations evolving with our patients in the future?

DR. CHEN: When we were in the operating room today, the resident actually remarked about the disclaimer on the screen. "The surgeon takes full and absolute responsibility for everything that this robot is doing." Therefore, when I am using the robot in surgery, I am explicitly saying that any mistakes are 100% my fault. From the company's perspective, it is meant to absolve them of any responsibility. At the end of the day—just like working with residents, fellows, or medical students—I am fully responsible. The old line of "garbage in equals garbage out" holds true for any technology. If I don't provide the right information for the system to execute the procedure, I will get junk out, and I am responsible for the outcome.

DR. KWON: It's multifactorial. Surgically speaking, the systems are only as good as the registration provided by the bony landmarks. There is also a robotics system that does not require cross-sectional imaging for preoperative planning. It requires a form of trust from the surgeon point-of-view. The system needs to convert 2-dimensional plain radiographs into 3-dimensional modeling, and this conversion requires trust by the surgeon in the system.

There are some systems, particularly in spinal surgery, where the representative is templating parts of the surgery—for example, placement and trajectory of pedicle screws. If there is an increasing reliance on companies, does it create a new dynamic in the setting of a catastrophic complication?

DR. KWON: Redundancy in the system is necessary. A single misstep must not lead to catastrophic complication. These outcomes must depend on how the surgeon plans and executes the steps of surgery. In the learning curves of operations, it is common for surgeons to stop, check imaging or preoperative plan, and assess if things are going well. Sometimes with navigation—as in conventional surgery—a time comes where things do not look right. You need to have the expertise to perceive this and override what you are seeing on the screen. This may be one of the major challenges with semi-active or haptic systems where the surgeon may be somewhat constrained by the device.

Is the interaction with company representatives or reliance on their presence going to change in the future?

DR. CHEN: It is likely to change with time, especially with different skill sets needed for different technologies. Company product specialists certainly know their system well and are trained on what to look at and what to do, but they don't always have the same clinical correlation as the surgical team. A joint surgeon I know has a particular method of performing TKA, and it works very well. A dynamic occurred in the operating room where the product specialist was trying to tell the surgeon what to do based on company training. While representatives can add value to a case, they should not take the role of the surgeon. It is important to have a company representative present for newer technologies, such as robotic surgery, but there does not need to be a product specialist and another representative opening boxes. This can be done by a single person. Worldwide, there is a movement to representative-less systems, but having a product specialist is helpful, especially in the beginning of implementing a new technology.

DR. MELNIC: The biggest benefit in having a rep present, is that you often do not know what surgical nurse or tech will be in your room on a given day. If you have consistent teams, this may not be the case. However, if you are doing cases after-hours or if you have someone who is not seasoned in arthroplasty, the presence of a rep is helpful.

DR. KWON: I do not have a rep in my room for primary cases. If you have a consistent team that works well, I do not feel that a rep necessarily adds value to a non-robotic, primary arthroplasty. However, I can see the utility of having a rep present initially as the team becomes accustomed to utilizing the robotic system.

"The learning curve is real."

What is the process for implementation? Courses, labs, or observation of other surgeons?

DR. CHEN: I had a senior partner at a previous practice who could do a total knee in 24 minutes; he was an incredible surgeon. He was asked by a company to participate in a study, and his first total knee took 2.5 hours. After this, I received a phone call asking me—the junior partner—to participate in this study, so he did not have to perform 2.5 hour robotic total knees every time. I enjoyed using it, so I first implemented the robot in an experimental context. I was exposed to a setting where I was able to watch my senior partner implement and utilize the system, and this was beneficial. The company required certification involving cadaver labs as well as the opportunity to observe other surgeons.

DR. KWON: The learning curve is real. My first experience was 6-7 years ago with a robotic system from a small company. We were provided the system in order to perform research looking at *in vivo* kinematics for THA application. This was my introduction to—and the context in which I learned—the robotic system. At that stage in the robotic product, you had to travel to the industry headquarters for cadaver training sessions, but there was no formal certification

process. I found the first few cases took nearly 3 times the usual surgical time—mainly because I was not used to the workflow. One of the challenging adjustments was actually placement of the fellow and/or the resident in the room to efficiently contribute to the surgery while not impairing any communication between a sensor and the system. As expected, workflow improved as more cases were performed, however it is important to note that effectively navigating a learning curve is an active—not passive—process. After each case, you need to reflect to determine what aspects went well and which others could have been improved.

DR. MELNIC: My training programs did not utilized robotic systems, so my exposure was through presentations at the AAOS or AAHKS followed by cadaver sessions locally.

Is there incentive to implement robotics into your practice?

DR. MELNIC: The technology is not quite advanced enough, but eventually it will be. When it reaches that level, even high-volume surgeons will be utilizing this tool to care for their patients. At some point, you have to make the leap and begin the journey. Also, I love to teach. Residents and fellows are interested in the technology, so I want to be able to teach our future generation of surgeons.

How do you think the use of robotics will affect training residents and fellows? Do you think they will have more or less autonomy?

DR. KWON: I think the robotic platform is a very useful, educational and research tool. With knee applications, we teach balancing flexion and extension gaps and how making particular cuts in a certain step influences the balance in the knee. The robotic system can give a much more visual experience for the residents. When placing an acetabular component, we rely on internal, anatomical landmarks. With robotics, you can learn if placement of the component is truly the position you are aiming for through the representation seen on the screen. For the residents and fellows, it would be a useful learning tool. For me, at the moment, the first utility and indications to use the robot would be research. There are a lot of research questions that we are not able to achieve without the robot, because we do not have the precision to measure it. The second would be the educational value.

DR. CHEN: It is a really good teaching tool for residents and fellows. We haven't quantified robots as a teaching tool, but it is an area of research where we can combine both of those points together in one. I would want to have senior residents or fellows use the robot; junior residents need to learn manually. However, it is great to walk residents through the balancing steps of the robot. You can really see what external rotation, internal rotation or varus/valgus does to change the gaps. From a pure teaching perspective, even if you are not using the robot, there is a Touch Surgery app that you can utilize to manipulate an implant and change the gaps. These maneuvers solidify the 9 x 9 grid you see in textbooks with regards to the TKA flexion and extension gaps. You can really visualize the mechanics of a total knee using these systems. From an attending's perspective, once the plan is set, my heart rate and blood pressure go down. Once those cuts are set, less can go wrong versus setting every jig in a manual case.

DR. MELNIC: Dr. Chen brings up a good point. For example: You're a busy arthroplasty surgeon who has 6-8 cases booked in a day, and your robot goes down. Do you cancel all your cases for the day if you're not comfortable doing the cases manually? It highlights the need to understand the basics.

What are some of the technical challenges you have encountered? What are some obstacles that need to be overcome? What are the challenges that you heard in implementing these systems?

DR. CHEN: We have never had the system go down. One time, we shut the robot down and turned it back on; it had been idle for too long. Because of the possibility the robot may go down, I consent every patient for their joint replacement "with or without robotic assistance." If the robot goes down, I still have my backup jigs, but that requires you to know how to do the case manually, to Dr. Melnic's point.

While the robot has never gone down, more common problems include: arrays being bumped or moved or check points being moved. In those cases, the points might need to be re-registered and I might have to start from ground zero. Manual jigs are available to complete the case if needed.

DR. KWON: In my experience, one of biggest challenges was placing the pins accurately and securely in one of the first generation robots. I'm sure things have come a long way. Those pins were very big and had to be spaced in a certain way from the surgical wound. The initial version was a reference into the iliac crest. For me, learning to incorporate placing pins was not a part of what we normally do. Correct placement of the reference to maximize the registration has been the biggest challenge. I don't believe that we have had any times where the robot, even with the first generation, stopped working. We did, however, get erroneous readings that we had to override manually. They may have been based on incorrect placement of the pins and/or inaccurate registration—especially in the much earlier software we had at the time.

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How do you discuss robotics to your patients, particularly when consenting them?

DR. CHEN: When discussing robotics with a patient, I always start the conversation with the risks and benefits of a total knee replacements. I operate at two hospitals, Brigham and Women's Hospital (BWH) and Brigham and Women's Faulkner Hospital (BWF). I ask patients if they have a hospital preference. If a patient is relatively complex or prefers to undergo surgery at BWH, then it's the end of the discussion, because there is no robot at BWH. I perform the case manually. If a patient chooses BWF or if he/she does not have a preference, then I tell the patient they have the option of undergoing the surgical procedure using the robot. Most people ask, "What is the benefit of the robot?" I tell them it is a more precise tool than our current instrumentation. Some patients state, "I don't want the robot doing the surgery, I want you to do the surgery." I explain that I am always doing the surgical procedure, but the robot acts as a tool. Other common questions asked are, "What do you prefer? What would you want for your own knee?" These are difficult questions, because although we do have good data on partial knees, we do not have the long-term data on total knees. I tell them honestly that the data is too early to say, and I don't have long-term outcomes. I like doing total knees with the robot for the precision of the instrumentation, but it is not needed to complete the operation. I really leave it up to the patient, and I give them a brochure. Some patients will make a decision at that point while some will read the brochure, go home, then decide whether they want robotic surgery. Regardless, I consent them for with or without robotic assistance, and if they choose manual instrumentation then I'll do the case manually.

How do you balance the marketing of robotic systems? Institutions market because patients are looking for it. How do you deal with companies engaging in direct-to-consumer marketing?

DR. CHEN: Industry is not allowed to market on Partner's behalf. This could be a positive or negative depending on perspective. Partners markets robotic technology in general and always want to make it company and surgeon agnostic. They are not marketing it for a single surgeon, which I think is ideal. I strongly believe robotics should be marketed as a group. In the arthroplasty division, we function as a group in which different surgeons offer different skills that patients are seeking. These include custom implants, direct anterior approach for total hip replacements and robotics.

However, this question does bring up a good point. There are many people in the community who obtain robots for orthopaedic surgery and do it for marketing purposes. This is not a good reason for implementing a new technology. As Drs. Melnic and Kwon pointed out, you want to adopt technology to benefit your patients or use as a teaching tool. You don't want to adopt technology just for marketing as the technology may be used incorrectly.

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Given that we are moving towards bundled payment models, how are robots going to affect costs in this new payment system?

DR. KWON: In terms of agreeing to and formulating the bundled payment model, patient outcomes is an important consideration. This would require good evidence and supporting data. So—in contrast to the conversation about marketing—we would require more robust data to suggest there is a patient outcome benefit using robots.

DR. CHEN: I agree with Dr. Kwon. Hopefully, it is going to elevate patient outcomes, but the robot has to deliver. I would add that robots—in general—are a capital cost. The robot is capital cost to the hospital itself and is amortized over time. It is not factored in the bundled payment. That said, it does go into the hospital's bottom line. You will notice new, cheaper, robots coming out, and that due to price, hospitals may start buying those robots regardless of outcomes. To Dr. Kwon's point, we have to show better outcomes or better benefits in order justify the use of a robot to the hospital.

With regards to bundled payments and robotics, the cost of the disposables associated with robotic use does come out of the bundle. The most expensive portion of bundled payments is the length of stay in the hospital and post-operative care. If a technology exists that could keep patients out of nursing homes and rehabilitation facilities, it would really improve the bundle as it would be included in the entire episode of care. The bundle includes the surgery, time in the hospital, and 90 days after surgery.

Thank you for participating. It was a meaningful discussion about a technology that we are all going to be implementing and adapting with as our careers go forward.