The Learning Curve of Robotically-Assisted UKA

R Jinnah, MD; CJ Lippincott, BA; S Horowitz, BS; MA Conditt, PhD

1Wake Forest University Baptist Medical Center, Winston-Salem, NC; 2MAKO Surgical Corp, Ft. Lauderdale, FL
mconditt@makosurgical.com

Introduction: Successful clinical outcomes following unicompartmental knee arthroplasty (UKA) depend on accurate component alignment, which can be difficult to achieve using manual instrumentation. A new technology has been developed using haptic robotics that replaces traditional UKA instrumentation. Integrating new technology into the operating room can be associated with a significantly long learning curve, which introduces inefficiency in to the surgeon’s practice and the hospital’s OR workflow. This study quantifies the learning curve of a new technology developed to improve the accuracy of UKA.

Methods: Eight hundred ninety-two patients received a UKA performed thirteen different surgeons with a robotically guided implantation system employing a CT based pre-operative plan implemented using a haptic-guided burr for all bone resection. Each surgeon had performed at least 30 surgeries with the new technology. As the philosophy of each surgeon differs in terms of tourniquet use, the time from the insertion of the first bone pin to the acceptance of the final trial components was measured. This time frame includes attachment of navigation markers to the femur and the tibia, three-dimensional registration of actual bony surfaces to the digital reconstructions, and bone resection. The surgical time of the final 20 surgeries of each surgeon was averaged for a steady state surgical time. For each surgeon, the number of surgeries required to have 2 consecutive and 3 total surgeries completed within the 95% confidence interval of the steady state surgical time of that particular surgeon was also noted.

Results: Surgical Technique:
- Patient specific pre-operative CT scans are used to create 3D model reconstructions of the femur and tibia and are then combined with 3D computer-aided design models of the implant components
- Pre-operative planning of implant position, overall leg alignment, gross anatomical deformities, overlapping of components through flexion, and geometric alignment of varus/valgus measurements is performed using the patient specific 3D bone models
- Intra-operatively, bicortical surgical navigation markers are placed in the femur and tibia and also mounted on the robotic arm to be recognized by a standard optical infrared camera. This allows the robotic arm burring tip to realize the relative position of the bone
- Bony landmarks are identified and digitized to register actual bone geometry to the virtual 3D reconstruction to allow real time tracking and adjustments to obtain correct knee kinematics and soft tissue balancing to finalize the implant volume to be resected (Figure 1).
- The robotic arm facilitates controlled bone resection by applying stereotactic boundaries to the cutting burr tip; these boundaries are virtual walls created by the software and implemented through the robotic arm hardware to restrict the cutting tip to within the predefined resection volume, which is defined by the shape of the implant and depth of resection (Figure 2).
- Permanent graphical feedback on the navigation screen visualizes the actual achieved versus the planned cavity, specifically based on preoperative planning
- Once both the tibial and femoral cavities have been prepared, component trials are inserted and a complete flexion-extension arc is performed in conjunction with computerized simulation of the implants in situ showing actual overlapping of implants and determining leg alignment and knee gap kinematics; Once trials are accepted, they are replaced with cemented implant components and a final range of motion is performed to compare with the trials.

Results: Surgical Times: The average surgical time for all surgeries across all surgeons was 56 ± 20min (range: 22min to 180min). This includes both the learning curve cases as well as the steady state cases. The surgeon with the shortest steady state surgical time averaged 38 ± 9min, while the surgeon with the longest steady state surgical time averaged 70 ± 29min. The average number of surgeries required to have 2 consecutive surgeries completed within the 95% confidence interval of the steady state surgical time was 16 (range: 4 to 42). The number required to have 3 surgeries completed within the 95% confidence interval of the steady state surgical time was 13 (range: 5 to 29).

Conclusion: New technology has been introduced that essentially replaces traditional manual instrument sets with a passive robotic arm that precisely executes a pre-operative plan. The learning curve of this novel surgical technique is reasonable and is much shorter than has been reported with the introduction of other orthopedic technologies in the OR. For example, the efficiency learning curve associated with using surgical navigation for TKA has been reported to be around 30 cases. New techniques such as hip resurfacing have been associated with learning curves as high as 70 cases. While the surgeons in this study may be classified as early technology adaptors an average learning curve of 13 cases is very promising for the acceptance of this novel robotic-guided surgical technique.

Figure 1: Knee Gap Kinematics are displayed in real time.

Figure 2: Graphical visualization of bone resection showing real time feedback of the burr, indicating what remains to be resected (green).

Figure 3. Typical learning curve graph showing one surgeon’s first 50 cases.

Paper No. 407 • 56th Annual Meeting of the Orthopaedic Research Society