Computer-Assisted Navigation in Hip Resurfacing Arthroplasty
A Single-Surgeon Experience

John S. Shields, M.D., Thorsten M. Seyler, M.D., Cara Maguire, B.S., and Riyaz H. Jinnah, M.D.

Abstract

Hip resurfacing arthroplasty is a technically challenging procedure, and orientation of the femoral component is critical to avoid implant failure. The use of computer-assisted navigation has been shown to decrease the learning curve for beginners in hip resurfacing and to improve the surgeon’s ability to produce consistent results. Computer navigation offers real-time feedback, with the opportunity to produce improved repeatability to optimize patient outcomes. The purpose of this study was to evaluate the learning curve of computer-assisted surgery in the hands of an experienced hip resurfacing surgeon. A retrospective review of 100 consecutive navigated hip resurfacing arthroplasties in 94 patients assessed preoperative and postoperative neck-shaft angles, operative times, and complications. Twenty-five non-navigated hip resurfacing arthroplasties, performed by the same surgeon, were evaluated as a matching group. Mean operative times for the computer-assisted hip resurfacings were 101 minutes, as compared to 104 minutes in the non-navigated group. We found that in the hands of an experienced hip resurfacing surgeon, the addition of computer-assisted navigation had no effect on the learning curve, but did provide feedback and repeatability to the surgeon.

Total hip arthroplasty (THA) has served as the treatment of choice for osteoarthritis of the hip in the elderly and has demonstrated excellent results in this sedentary population. Long-term outcomes of THA for the younger, more active population have been less encouraging, with early implant failure and revision surgery.¹⁻¹ With recent advances in metal-on-metal bearing surfaces, hip resurfacing has re-emerged as a viable option to potentially improve implant longevity and patient outcomes.⁴⁻⁵ Hip resurfacing arthroplasty preserves proximal femur bone stock and may allow better stress transfer, reduced dislocation rates, an easier revision surgery, and a higher level of activity than THA.⁵⁻⁸ Disadvantages of hip resurfacing devices include a lack of modularity, a steep learning curve of a technically demanding procedure, and highly selective patient criteria.

Femoral neck fracture is a unique complication, with rates varying from 0% to 17%.⁹⁻¹³ Several risk factors, including patient and surgical factors, are associated with this complication. Fractures typically occur within months of the procedure and are responsible for nearly 60% of early revisions.¹¹⁻¹³ Patient risk factors include age, body mass index (BMI), gender, and poor bone quality (resulting from osteopenic bone), large femoral cysts, or necrotic bone.⁹⁻¹¹⁻¹³ Various surgical risk factors increase the potential of femoral neck fractures, including the amount of surgeon experience with the technique, incomplete seating of the femoral component, notching of the superolateral aspect of the femoral neck, and varus placement of the femoral component.⁹⁻¹¹⁻¹³ Orientation of the femoral component to optimize the femoral stem-shaft angle, using a valgus insertion technique relative to the neck-shaft angle during the preparation of the femoral head, is important to reduce stresses transferred through a narrow zone in the head-neck region.¹²⁻¹³⁻¹⁵⁻¹⁸ Shimmin and Back, in a review of 50 cases of femoral neck fractures after hip resurfacing, found varus alignment of the femoral component was greater than 5° in 71.1% of the patients when compared with the preoperative femoral neck-shaft angle.¹⁵ They also found notching of the superior aspect of the femoral neck in 46.6% and both notching and varus orientation in 36%. Similarly, Beaulé
and colleagues analyzed the orientation of the femoral component in hip resurfacing and observed that hips with an adverse outcome had a significantly lower mean stem-shaft angle than the rest of the cohort (133° vs 139°, p = 0.03). Fifteen femoral components with an insertion angle of less than or equal to 130° had an increase in the relative risk of an adverse outcome by a factor of 6.1 (p < 0.004).

Hip resurfacing is a technically demanding procedure with a steep learning curve, and surgical experience has been linked to both notching of the femoral neck and varus alignment of the femoral component. With the development of imageless navigation, studies have shown that this new technology serves to avoid component malpositioning during the surgeon’s learning curve and provides more accurate and consistent insertion of femoral components. As the procedure becomes more common, the younger, more active patient population is demanding hip resurfacing procedures, new technologies seek to reduce the learning curve and decrease complication rates in the less experienced surgeon. At the same time, experienced surgeons are interested in imageless navigation technology, as it provides instant intraoperative feedback about component positioning and allows for consistent repeatability of femoral component alignment. The primary purpose of the current study was to assess the learning curve of resurfacing surgery with imageless navigation in the hands of an experienced resurfacing surgeon.

**Materials and Methods**

After obtaining Institutional Review Board approval, 100 metal-on-metal total hip resurfacings in 94 patients were retrospectively reviewed. The resurfacings were performed by a single fellowship-trained surgeon, with resurfacing experience of more than 250 hip resurfacings without navigation. The study resurfacings were performed between July of 2007 and December of 2008, at a single institution, using identical surgical technique and implants, and performed with the aid of computer-assisted surgery. Data was collected on all 100 cases and included gender, age at the time of surgery, BMI, operative time, postoperative complications, and digital planning. Standard anteroposterior (AP) radiographs taken in the preoperative and postoperative period were evaluated to measure neck-shaft and stem-shaft angles, respectively. There were 24 females and 70 males, who had a mean age of 49 years (range, 19 to 68 years). The 100 hips were arranged chronologically by operative date and broken down into four groups of 25. Data also was gathered on 25 non-navigated hip resurfacings to serve as a matching group.

All operations were performed through a routine posterolateral approach. The femoral head was prepared for navigation with the use of the BrainLAB VectorVision Hip SR Essential 1.0 system (BrainLAB, Feldkirchen, Germany). A 5-mm threaded pin was placed into the lesser trochanter with an optical array attached, being careful to keep the metallic array free of blood and tissue that would interfere with the signal. The stationary pin array served to establish a coordinate between the patient and the BrainLAB navigation system. Four landmarks were then identified using navigation pointers that included the medial and lateral epicondyles, the piriformis fossa, and the femoral head-neck junction. Once this was complete, the pointers were used to gather five sets of individual points around the femoral neck so that a three-dimensional bone model could be created by the navigation system, along with an automatically generated plan. The three-dimensional model was confirmed and the plan then could be adjusted to guarantee optimal fit and avoid notching and malposition of the implant. Once the plan was chosen, a 2.4-mm guide-wire was inserted into the proximal femur with the aid of the navigated drill guide, which provided constant feedback from the BrainLAB navigation system. The femoral head was then prepared with the standard over-drill and reamers.

Once the proximal femur had been reamed, it was dislocated anterosuperiorly, and the acetabulum was exposed with the aid of an inferior curved retractor. The acetabulum was cleared of soft tissue and sequentially reamed to 1 mm under the intended diameter of the acetabular component. The acetabular component was then impacted and attention was turned back to the reamed femoral head, where the femoral component was cemented into place. The hip was reduced, thoroughly irrigated, and closed in layers.

The data were compiled and tabulated with use of Microsoft Excel spreadsheets (Microsoft Corporation, Redmond, WA). All statistical analyses were done with use of SigmaStat software (Systat Inc., San Jose, California). Descriptive statistics were calculated. Chi square statistics and a z-test for proportions were performed to evaluate statistically significant differences between proportions for all groups in the data set. Linear regression models were used in an attempt to determine the relationship between the primary outcome parameters [operating room (OR) time, complications] and dependent variables, including BMI, surgeon experience, and implant positioning. A p value of < 0.05 was considered significant.

**Results**

There were no significant differences found between the four groups and matching groups with respect to patient variables, including age, BMI, or gender (Table 1). There were also no significant differences found among the groups with respect to OR time (p = 0.565). The mean OR time for all 100 navigated hips was 101 minutes compared to a mean of 104 minutes for the matching group (p = 0.924). Using linear regression analysis, the only variable that was found to influence OR time was BMI (p < 0.001). By linear regression analysis, OR time was found to increase with increasing BMI (Fig. 1). There were four complications, three in group 2, including loosening of the acetabular component, a femoral neck fracture requiring revision to a total hip arthroplasty, and one dislocation requiring a revision.
hardware retention, irrigation, and debridement, along with required intravenous antibiotics. The matching group had one superficial wound complication and one hip dislocation.

The mean actual stem-shaft angle (SSA) of the groups became more valgus over time, with group 1 having an SSA of 139°; group 2, an SSA of 140°; group 3, an SSA of 142°; and group 4, an SSA of 144°. Compared to the preoperative neck-shaft angle, the postoperative stem-shaft angle for 89% of the femoral components was inserted in a valgus position, with 96% of those in group 4 being inserted in a valgus position. The matching group had only 80% of the cases with the stem-shaft angle inserted in valgus. When comparing the planned stem-shaft angle on the BrainLAB system to the actual stem-shaft angle, there was a narrow range in groups 1 and 2, with a mean of 0° (range of 7° varus to 5° valgus and 5° varus to 5° valgus, respectively), and a wider range in groups 3 and 4 (ranges of 8° varus to 7° valgus and 7° varus to 12° valgus, respectively). A summary of the data can be found in Table 1.

### Discussion

In the hands of an experienced resurfacing surgeon, there was no learning curve observed with the addition of imageless navigation. There was no difference in mean OR times between navigated (101 minutes), compared to non-navigated hips (104 minutes). Group 1 had the fastest OR time of 99 minutes, with group 3 having the longest OR time of 105 minutes. This might be explained by the fact that as the new technology was introduced, the first 25 patients (group 1) underwent the procedure entirely by the faculty surgeon, who had a mean OR time of 99 minutes. As the attending surgeon became more comfortable with the new technology of hip resurfacing, he began to introduce and teach the technology to residents in group 3, which explains the increase in OR times as he went along.

Hodgson and coworkers evaluated the surgical performance of residents and fellows with no resurfacing experience to experienced hip arthroplasty surgeons in a cadaver study, comparing repeatability of guide-pin axis positioning in computer-assisted and manual femoral head resurfacing arthroplasty. They found that navigation allowed for better varus-valgus and mid-neck placement of the femoral component, as compared to mechanical guides. The data also supported that applying computer-assisted surgery for femoral head resurfacing can be quicker than using the manual technique, independent of surgeon experience, and with improved repeatability. Seyler and associates reported that when comparing experienced hip resurfacing surgeons, lesser experienced hip resurfacing surgeons, and inexperienced supervised senior residents using computer-assisted navigation to faculty using traditional methods for hip resurfacing surgery, those using computer navigation had a reduced range of error, optimized implant alignment, and a decreased learning curve.

The effects of navigation on the learning curve of hip resurfacing in the inexperienced hands of medical students was evaluated by Cobb and colleagues, who used synthetic proximal femoral models to place guide-wires with the use of navigation.
of mechanical guides, computed tomography (CT), or navigation. The mean error using the conventional method to insert the guide-wire was 23°. Using the CT plan method, the mean error was 22°; there was a mean error of only 7° using navigation. The investigators concluded that navigation plays an important role in reducing the learning curve in hip resurfacing arthroplasty and helps to place components with a higher degree of accuracy.

Conclusion

Our investigation found that providing an imageless computer-assisted navigation system to an experienced hip resurfacing surgeon offered the benefits of navigated surgery, with no learning curve effect. Computer-assisted navigation can help the learning curve of a technically demanding procedure in inexperienced surgeons, as described by the literature, while placing real-time feedback and consistent repeatability into the hands of an experienced surgeon.

Disclosure Statement

Wake Forest University Department of Orthopaedic Surgery receives research funding from Smith and Nephew (Memphis, TN).

References