Robotic-assisted revision knee arthroplasty: a retrospective case series analysis of complex revision cases

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Foreword from Thorsten Seyler, MD, PhD

Dr. Thorsten Seyler is an Orthopaedic surgeon and Assistant Professor of Adult Reconstruction at the Department of Orthopaedic Surgery at Duke University School of Medicine. Dr. Seyler's research interests involve investigating systematic approaches to problem solving, with a focus on complex cases in adult reconstruction, most notably in the setting of revision arthroplasty.

"Revision knee arthroplasty presents unique technical challenges and decision-points for the orthopaedic surgeon. Although the survivorship of knee arthroplasty has improved over time, the increased volume of primary knee replacement has led to an increased number of revision procedures. In my review of the Swedish Knee Arthroplasty Register (SKAR), Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), and the Kaiser Permanente Joint Replacement Registry (KPJRR), mechanical loosening and instability are listed among the 5 most common reasons for revision procedures. The current standard of care requires accurate implant failure diagnosis and meticulous pre-operative planning. However, accurate assessment of bone loss and stability based on pre-operative imaging is difficult, if not impossible for the majority of cases. The value with an imageless robotic-assisted system such as the handheld CORI◊ Surgical System includes the ability to perform revision surgery without pre-operative imaging, intra-operative real time bone loss assessment, bone preserving resection, reduction in surgical time, improved alignment accuracy and intra-operative gap balancing to avoid instability and post-operative pain. As I have experienced, the ability to perform revision knee arthroplasty using the handheld CORI Surgical System with RI.KNEE Robotics software also enables surgeons to perform these procedures with a reduction in trays compared to conventional techniques, leading to cost savings for health systems."

Summary

- The Smith+Nephew CORI Surgical System with RI.KNEE Robotics software is the first robotics platform indicated for use in revision knee arthroplasty[1]
- The clinical burden of revision knee arthroplasty is anticipated to rise in the future.[2] However, surgical challenges remain in restoring knee joint alignment,[3] addressing bone loss,[4] and balancing flexion/extension gaps[4]
- Robotic-assisted revision knee arthroplasty may help mitigate pervasive challenges in this procedure, as robotics use has been associated with improvements in post-operative range of movement (ROM), functional outcomes and knee alignment, compared to pre-operative values[5]
- In a retrospective case series, Smith+Nephew handheld robotic-assisted revision knee arthroplasty was successfully applied across a wide range of complex revision cases and represented a reproducible, safe and familiar technique
- Surgeon benefits of Smith+Nephew handheld robotic-assisted platforms for revision knee arthroplasty include the ability to refer to old and new joint line parameters, as well as the objective evaluation of ligament laxity

Introduction

The rate of primary total knee arthroplasty (TKA) is projected to grow in future decades.[2,6–8] This increase is driven in part by constantly aging populations, as well as other risk factors such as osteoarthritis and obesity.[2] Advancements in long-term outcomes have led to increased numbers of TKAs performed in younger, more active patients.[2] With an estimated 5% of all TKAs requiring revision surgery ten years post-operatively,[9] a corresponding increase in the rate of revision knee arthroplasty is expected. One study projected that the number of revision TKAs performed in the United States will increase by up to 182% between 2014 and 2030, concluding that the clinical burden of revision knee arthroplasty is likely to increase substantially.[2,10]

Revision knee arthroplasty is a technically demanding procedure which poses several challenges, such as restoring the anatomical femoral joint line,[3] addressing bone loss[4] and achieving balanced flexion/extension gaps.[4] Failure to achieve these surgical goals may be associated with negative impacts on patient outcomes. Some studies suggest that failure to restore the femoral joint line has been associated with reductions in post-operative ROM,[3,11] flexion and extension[3] and Knee Society Scores (KSS).[3]

Robotic technology in orthopaedic surgery is increasingly used to complement conventional surgical procedures and has been shown to improve the ability of surgeons to reproduce alignment of the knee compared to conventional techniques.[12] The use of robotic technology enables an individualised surgical approach through pre- and intra-operative planning[13] which is not only designed to allow for optimal implant sizing and positioning, but also provides a personalised approach to soft tissue balancing. Therefore, use of robotic technology may contribute to overcoming some of the additional challenges seen with revision knee arthroplasty.

The Smith+Nephew CORI◊ Surgical System with RI.KNEE Robotics software is now indicated for use in revision knee arthroplasty.[1] CORI is designed to deliver image-free smart mapping, real-time planning and gap assessment, optimised alignment and balance, and safe and accurate robotically-controlled resection.[14] In a previously published single-centre, prospective study of 10 patients undergoing revision knee arthroplasty, use of Smith+Nephew handheld robotics was associated with improvements in post-operative ROM, Oxford Knee Score (OKS), KSS and leg alignment, compared with pre-operative values.[5] Furthermore, no mechanical axis outliers were reported.[5]

Methods

A retrospective analysis of the performance and adverse events of Smith+Nephew handheld robotic-assisted revision knee arthroplasty was performed across a diverse series of complex revision cases. Data were retrospectively collected by a single surgeon. Inclusion criteria were cases performed using a Smith+Nephew handheld robotic platform*, Smith+Nephew associated TKA workflow, and Smith+Nephew knee implants (JOURNEY◊ II TKA and LEGION◊ Total Knee System).

Patient characteristics

The demographics of patients included in the cohort are depicted in Table 1.

Table 1. Patient demographics

Patient characteristic	Value
Female/male, %	44/56
Mean age in years (range)	66.5 (51–77)
Mean BMI (range)	32.9 (24–38)
Proportion classified as obese (BMI>30), %	78

Revision knee procedure characteristics

Patients underwent revision knee arthroplasty procedures for a range of reasons (Figure 1). The characteristics of revision procedures across the cohort are presented in Figure 2.

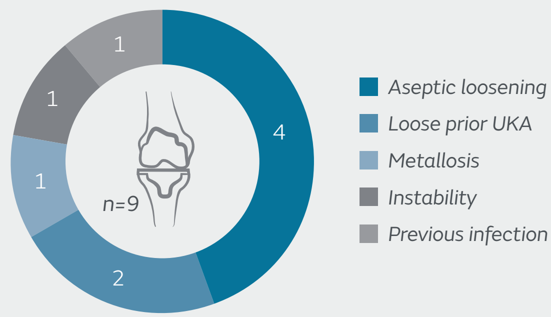


Figure 1. Reasons for revision surgery
UKA = unicompartmental knee arthroplasty

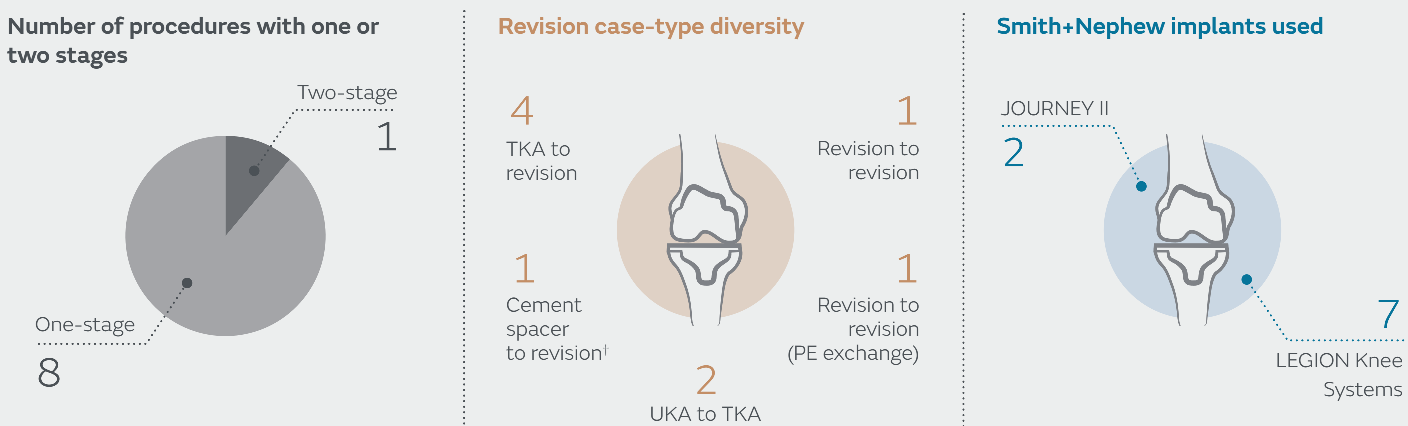


Figure 2. Summary of revision case characteristics
†A cement spacer was placed in the knee of this patient to treat an infection prior to their revision surgery.
TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty

*CORI or NAVIO◊ handheld robotics platforms

The majority of cases (n=8) were one-stage revision procedures; the two-stage revision procedure (n=1) involved a periprosthetic joint infection and subsequent replacement of a cement spacer with a revision implant system. Patients underwent a broad range of revision procedure types, and the cohort is considered to be reflective of the real-world diversity of revision cases. A LEGION◊ Knee System implant was selected in the majority of cases (78%; n=7). The JOURNEY◊ II TKA implant line was used in two cases (22%; n=2), specifically in those that involved revision from a unicompartmental knee arthroplasty (UKA) to a TKA implant.

Results

Smith+Nephew handheld robotics intra-operative workflow

Intra-operative, real-time planning using the Smith+Nephew handheld robotics TKA workflow is designed to achieve optimal joint line restoration, gap balancing through full ROM and accurate bone resection.[14]

Across all cases, the Smith+Nephew handheld robotics TKA intra-operative workflow was utilised successfully, without the need for pre-operative advanced imaging (ie. MRI, CT). As a result, imaging parallax/distortion and scatter and patient radiation exposure were avoided.

The step-wise workflow was reproducible and common features and functions were used for all cases. The gap assessment workflow and implant planning states utilising recorded gap collections were used across all case types, indicating the value to the surgeon of collecting joint laxity and gap balancing information during revision procedures. Case images of the implant planning screens are displayed in Figures 3a–c. Importantly, application of the Smith+Nephew handheld robotics TKA workflow to revision cases provided the surgeon with a familiar, consistent approach.

Figure 3a. Case image of implant planning screen utilising gap assessment information

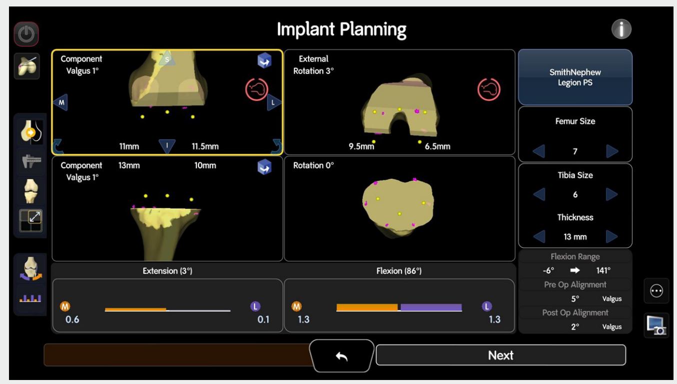


Figure 3b. Case image of implant planning screen where bony defects are visualised (purple annotations) and used for augment planning purposes

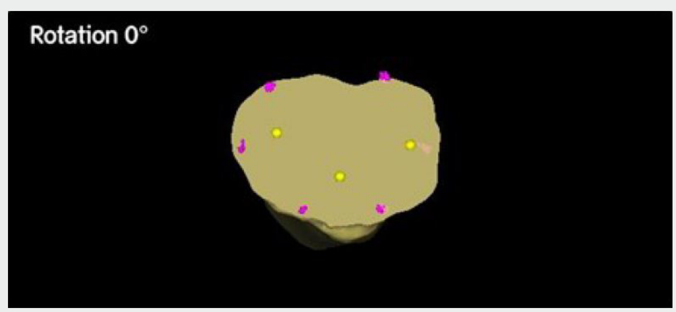


Figure 3c. Zoomed in view of bone model with purple annotations showing level of bony defect on the tibia

Bone preparation methods (femur and tibia)

The Smith+Nephew handheld robotic platform is designed to facilitate accurate bone preparation, with use of the robotic-assisted bur to achieve accurate bone removal based on the implant plan.[14] Case images of the femur bone removal workflow stage before and after execution of bone removal are displayed in Figure 4. In a majority of cases (8 of 9), the robotic-assisted bur was used for preparation of at least one bone interface (Figure 5).

The robotic-assisted bur was also used to prepare both the femur and tibia in all cases that required the use of augments (66%; n=6; Figure 5). This usage demonstrates the ability of the Smith+Nephew robotic platform to support the surgeon in planning for the use of augments, with the goal of ensuring accurate joint balancing and avoiding compromising joint kinematics during bone defect management. Augments were attached to the backside of implants used, providing a support structure that joined the implant to the remaining bone stock. Use of augments was not required in 33% of cases (n=3); these cases involved conversion of UKA to TKA with the use of JOURNEY II TKA (2 of 3) or where the polyethylene liner alone was revised for symmetric instability (1 of 3).

At the time of completion of this case series, no adverse events related to the use of robotic platforms or revision procedures performed were reported.

(a) (b)

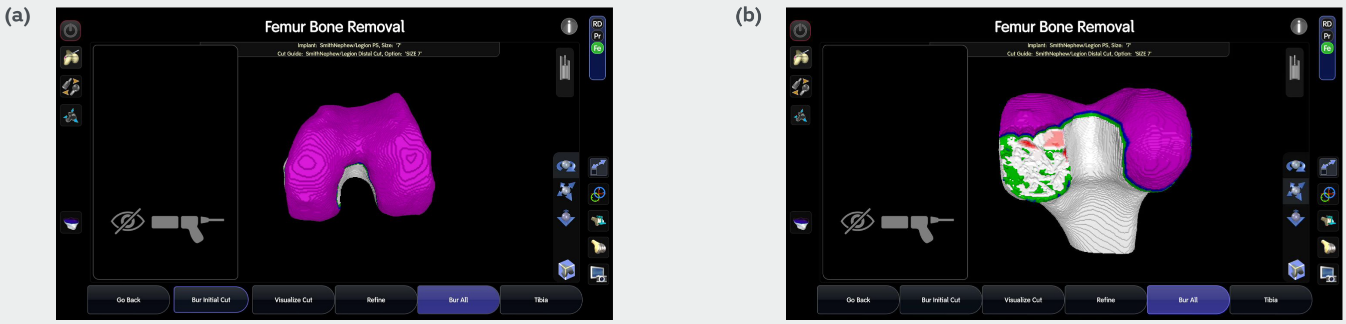
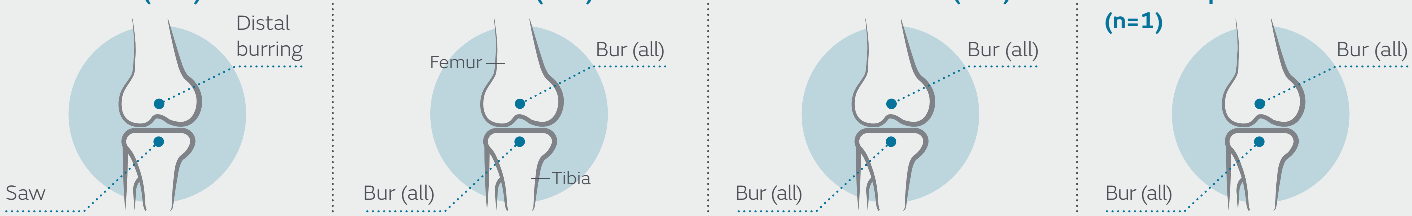


Figure 4. Case images displaying the femur bone removal workflow stage (a) before execution of cuts and (b) after execution of cuts for posterior augment using the burring functionality of the Smith+Nephew handheld robotic platform



	UKA to TKA (n=2)	TKA to revision (n=4)	Revision to revision (n=1)	Cement spacer to revision (n=1)
Augments used:	No	Yes	Yes	Yes
Augment bone preparation method:	N/A	Bur	Bur	Bur

Figure 5. Summary of femur and tibia bone preparation methods where the robotic-assisted bur was used

PE = polyethylene; TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty

Considerations

This retrospective case series highlights the diversity of revision cases that can be addressed with the Smith+Nephew handheld robotic platform and reflects the real-world variation of revision knee arthroplasty scenarios. There exists an opportunity to expand on these results with larger, prospective studies moving forward.

Conclusions

The Smith+Nephew handheld robotic platform for revision knee arthroplasty demonstrated successful application across a number of complex revision cases.

Further, the existing Smith+Nephew handheld robotics primary TKA workflow was used without any requirement for pre-operative advanced imaging and the workflow was reproducible and safe across a varied case-mix.

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