International Journal of Surgery Open 17 (2019) 8–14

Contents lists available at ScienceDirect

International Journal of Surgery Open

journal homepage: www.elsevier.com/locate/ijso

Research Paper

The "capsular noose": A new capsular repair technique to diminish dislocation risk after the posterior approach total hip arthroplasty☆

Todd V. Swanson [a, **], Mohit M. Kukreja [a, *], James C. Ballard [a], Henry G.M. Calleja [a], Jonathon M. Brown [b]

[a] Swanson Hip and Knee Center of Excellence and Research Institute, Desert Orthopaedic Center, Las Vegas, NV, USA
[b] Touro University Nevada College of Osteopathic Medicine, Henderson, NV, USA

A R T I C L E I N F O

Article history:
Received 1 March 2018
Received in revised form
25 December 2018
Accepted 26 December 2018
Available online 2 January 2019

Keywords:
Capsular noose
Capsular repair
Capsule
Dislocation
Posterior approach
Total hip arthroplasty

A B S T R A C T

Background: Post-operative hip dislocation has been commonly associated with primary THA as a troublesome complication after posterior approach. Although several other risk factors have been implicated, techniques of capsular repair and closure have also been described. A new technique for repair of the capsule after posterior, minimally invasive, total hip arthroplasty is described.
Methods: In Part A of this two-part study, 133 classic repairs of the capsule and external rotators to the greater trochanter (Group 1) were retrospectively compared to 144 capsular noose repairs (Group 2). After minimum 24-month follow up, dislocation was more common in Group 1 than in Group 2 (5.3% vs. 0.69%, $p = 0.02$). In Part B, 20 consecutive patients were tested intra-operatively for torque and internal rotation to dislocation using three capsular repair techniques.
Results: The capsular noose repair provided greater resistance to dislocation than no repair ($p < 0.01$) and to simulated classic repair ($p < 0.05$).
Conclusion: The capsular noose repair may reduce dislocation risk after posterior approach total hip arthroplasty.

1. Introduction

In concordance with the current trends for improvement of patient outcomes in Total hip arthroplasty, strategies are evolving mainly to decrease the incidence of perioperative complications and accelerate functional recovery. Dislocation remains a troublesome postoperative complication after total hip arthroplasty. Although causes of postoperative dislocation of the hip can be multifactorial and include patient-dependent factors like gender, previous hip surgery, dysplasia,neurological status and patient compliance [1–5], common causes under the surgeon's direct influence include component malpositioning and failure to restore soft tissue tension through accurate restoration of leg length and femoral offset. Surgical approach has also been shown to affect dislocation rates especially the posterior approach which classically carries the highest risk of dislocation when compared to the direct lateral, true anterolateral, and direct anterior approaches [6–8].

Traditionally, the posterior approach has been popular because of minimized blood loss and operative time, ease of exposure, minimal postoperative abductor weakness, and lower risk of heterotopic ossification [1,9–11]. However, the primary disadvantage of the posterior approach and the most crucial concern for the operating surgeon remains dislocation, with dislocation rates after primary total hip arthroplasty ranging from 3.23% to 6.9% [1,12,13]. Greatest risk for postoperative dislocation is in the first 12 weeks and about 60–70% of this proportion occurs during the first 6 weeks after surgery [14].

Although many authors advocate complete excision of the capsule, others more recently have described capsular repair techniques to reduce the incidence of dislocation [10,15–19]. Some have reported no dislocations in relatively large cohorts of patients undergoing these repairs. There is definite evidence that a secure repair of the posterior structures decreases the chances of dislocation after posterior total hip arthroplasty [9,20,21].

The senior author has used the posterior approach for primary total hip arthroplasty (THA) for over 25 years, and a posterior, single-incision, minimally invasive surgical (MIS) technique since

☆ Institution: Desert Orthopedic Center & Swanson Hip/Knee Research, Foundation, 2800 E.Desert Inn, Suit 100, Las Vegas,Nevada,USA-89121.

* Corresponding author.
** Corresponding author.
E-mail addresses: tswanson@minitotalhip.com (T.V. Swanson), drmohitkukreja@gmail.com (M.M. Kukreja).

https://doi.org/10.1016/j.ijso.2018.12.005
2405-8572/

May 1997. Until May 2001, a classic repair of the posterior capsular flap and external rotators to either the greater trochanter or gluteus medius tendon was performed to enhance stability of the hip. However, problems with the posterior capsular repair included a continued significant incidence of posterior dislocation, technical difficulty repairing the capsule in cases of a contracted posterior capsule, or disruption of the repair in the early rehabilitative period. Other authors have described similar difficulties [16,22,23].

Therefore, in May 2001, the senior author developed a technique to retain and repair the capsule, by advancing the postero-inferior capsule superiorly and repairing it to the superior capsular edge to create a tight, "noose-like" repair of the capsule around the prosthetic femoral neck (the "capsular noose" repair).

In order to determine whether this repair technique provided additional resistance to posterior dislocation of the hip, the authors performed the present study in two parts: Part A is a retrospective comparison of the dislocation rate using the classic posterior capsular repair to the greater trochanter or gluteus medius with the new, capsular noose repair technique. Part B is an intra-operative, mechanical study comparing the amount of torque and internal rotation required to dislocate the hip posteriorly with the hip flexed to 90° after a) no repair of the capsule, b) classic repair of the capsule to the greater trochanter or gluteus medius, and c) the new capsular noose technique.

2. Material and methods

2.1. Clinical study methods

Institutional Review Board approval was obtained for both parts of this study. For Part A of the study, demographic and clinical data were obtained retrospectively from 331 consecutive patients undergoing primary total hip arthroplasty by the senior author between May 2001 and October 2003.

All cases entailed a minimally invasive, posterior approach, as previously described by the senior author [24]. All patients received a cementless femoral component (SL-Plus [Plus Orthopedics AG, Rotkreuz, Switzerland], Accolade [Stryker/Howmedica, Mahwah, NJ], Proclass [StelKast, McMurray, PA] or Synergy [Smith & Nephew Orthopedics, Memphis, TN]) and a cementless, press-fit, ingrowth acetabular component (Reflection [Smith & Nephew Orthopedics, Memphis, TN], Provident [StelKast, McMurray, PA], EPF, Plus-Fit, or MPF [Plus Orthopedics AG] and Ultra high molecular weight (UHMW) polyethylene liners with an elevated rim placed posterosuperiorly were included. Patients with incomplete records or undergoing bilateral THA, revision THA, or THA secondary to a fracture or dislocation/neoplastic causes were excluded. Patients with less than 24 months follow-up who could not be located were also excluded.

Two groups of patients were defined based on the type of posterior soft tissue repair performed. In Group 1 (May 2001 to May 2002), the external rotators and posterior hip capsule were repaired with non-absorbable suture (#2 Panacryl) to the tendinous insertion of the gluteus medius and on the posterior aspect of the greater trochanter. In Group 2 (May 2002 to October 2003), the external rotators and capsule were closed with a new capsule-to-capsule repair technique as described below (the "Capsular Noose" technique).

Group 1 initially consisted of 179 patients: 69 were male (38.5%), 110 were female (61.5%) with an average age of 63.8 years (range 31–96). Group 2 initially consisted of 154 patients: 50 were male (32.5%), 104 were female (67.5%) with an average age of 62.9 years (range 31–85). Pre-operative diagnosis was predominantly osteoarthritis for both groups. Thirty-eight percent of femoral components in Group 1 were high offset, and 37% of femoral components in Group 2 were high offset.

The postoperative rehabilitation program was the same for both groups. Patients were allowed immediate full weight-bearing as tolerated and they began ambulation on the first postoperative day. All patients were treated by physical therapists in the hospital and later in their homes or in rehabilitation centers. Standard hip dislocation precautions were utilized. Abduction pillows were used while in bed for six weeks post-operatively in all patients in Group 1. Abduction pillows were abandoned after the first several months' experience in Group 2 because of stability demonstrated by the capsular repair. Also, the post-operative radiographs done for all patients were screened by a single surgeon, the Senior author of the article (T.V.S.) to rule out any gross errors in component positioning, a confounding factor of dislocation (iatrogenic) in this study. Standardized anteroposterior radiographs of the pelvis centered over the symphysis pubis were made available for measurement of the abduction angle of the acetabular component. The abduction angle and the leg-length discrepancy of each hip was determined in accordance with the criteria described in detail by Woolson et al. [2]. A cross-table lateral film was also analyzed to measure the anteversion angle of the acetabular component. Because it was not possible to determine the degree of femoral component anteversion from standard radiographs, data on femoral component anteversion could not be obtained.

2.2. Surgical technique

A posterior, single-incision, MIS technique was performed in all patients. The skin incision was placed at 30° to the axis of the femur according to a reproducible, geometric formula (Fig. 1). The axis of the femur is identified, the tip of the greater trochanter is marked with a spinal needle, and a simple geometric formula is applied to plan incision location. Incision length can be estimated by dividing patient body mass index by three as shown.

Incision length was based on the patient's body mass index (BMI) and generally equated to one third the BMI in centimeters. After skin incision and subcutaneous dissection, the gluteus maximus was bluntly split along its fibers taking care not to transect any muscle fibers. Appropriate retractors were placed and the short external rotators were exposed. A Hohmann retractor was then placed between the gluteus medius and minimus muscles near their insertions on the greater trochanter, and the piriformis

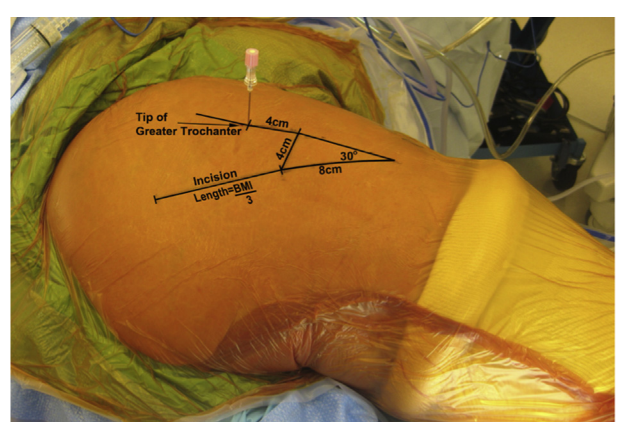

Fig. 1. Incision placement for posterior MIS total hip arthroplasty. The axis of the femur is identified, the tip of the greater trochanter is marked with a spinal needle, and a simple geometric formula is applied to plan incision location. Incision length can be estimated by dividing patient body mass index by three as shown.

tendon was identified. The capsule was then divided parallel and just inferior to the piriformis tendon, thereby preserving the tendon and its insertion to the greater trochanter. The capsulotomy was then angled inferiorly, releasing the capsule and four short external rotators directly from the proximal femur to the upper level of the quadratus femoris, creating an L-shaped capsular flap. The four external rotators (superior and inferior gemelli and obturator internus and externus) and the posterior capsule were released "en bloc." The hip was then dislocated posteriorly, the femoral neck cut made, and the total hip implants inserted in standard fashion.

Once the arthroplasty was completed, the inferior capsular flap was repaired to the posterior border of the superior capsular flap, the key points of which include-

1 The inferior capsular flap was advanced 2–3 cm proximally and closed to the superior capsule with heavy, non-absorbable suture (#5 Ethibond), essentially advancing the capsule and pre-tensioning its postero-inferior portion, similar to what is accomplished with an inferior capsular shift of the shoulder.
2 Typically, two or three figure-of-eight sutures are utilized.
3 The result is a "pseudo-anatomical" repair of the capsule, restoring the posterior "tension band" of the hip joint.
4 No tissue repaired to either the greater trochanter or the gluteus medius tendon

Fig. 2 illustrates the Capsular Noose Technique in detail.

3. Biomechanical study methods

Part B of the study compared the torque resistance and angular range of motion to dislocation between three different methods of managing the posterior capsule: a) no repair of the posterior capsule, b) transosseous repair of the posterior capsule to the posterior border of the greater trochanter or to the posterior boarder of the gluteus medius tendon as described by Pellici et al. [10], and c) the capsular noose/advancement technique as described above. Twenty consecutive patients undergoing primary THA using cementless Reflection acetabular components (Smith & Nephew Orthopedics, Memphis, TN and SL-Plus stems (Plus Orthopedics AG, Rotkreuz with 28 mm heads and standard offset stems were evaluated. This was a prospective selection of 20 patients which were apart from the Part A study population. They were randomly allocated to each repair subgroup and the study done in June to December 2003.

After implantation of the total hip components, the hip was evaluated three separate times by internally rotating it in a position of ninety degrees of flexion and neutral abduction. A tensiometer was attached to the ankle, and the distance from the axis of the femoral shaft to the tensiometer was measured in order to calculate the torque placed on the femoral shaft. The hip was internally rotated either until it dislocated or until the surgeon felt that any additional internal rotation would be unsafe and place the femur at risk of fracture. The first test was performed leaving the posterior capsule and external rotators unrepaired. The second test was performed after simulating a typical repair of the posterior capsule to the posterior greater trochanter or to the posterior border of the gluteus medius using several towel clips. The third test was performed after completing the capsular noose advancement as described above. Internal rotation torque was measured using the tensiometer, and angular measurements were made using a sterile goniometer (Fig. 3). Torque resistance and angular range of motion to the point of dislocation were recorded for each of the three capsular repair conditions.

4. Statistical analysis

In Part A of the study, the incidence of dislocation in the two groups was compared using the chi-square test with the Yates modification. In Part B of the study, comparisons between repair

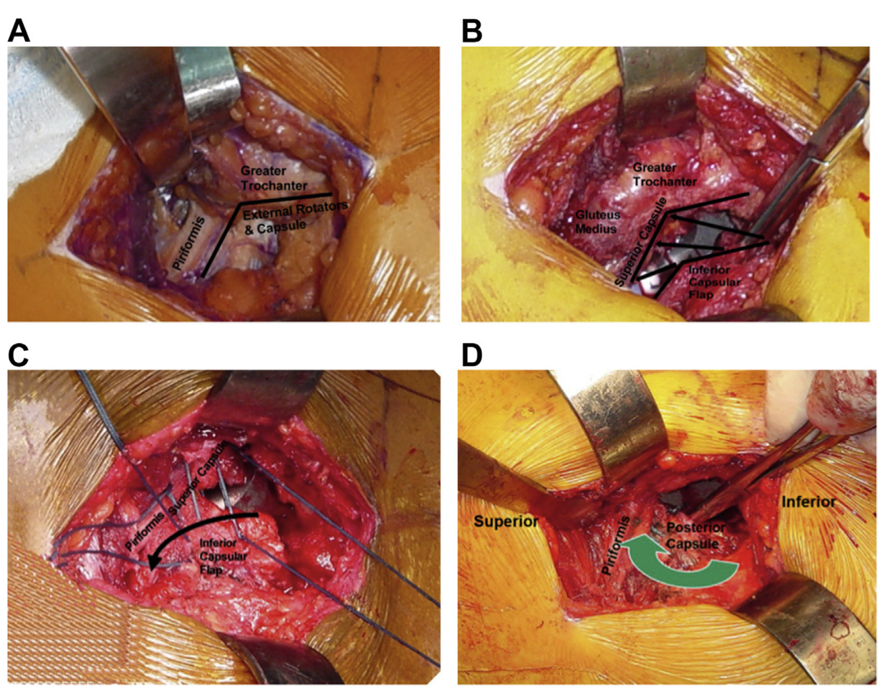

Fig. 2. The "CAPSULAR-NOOSE" procedure. 2A. The capsulotomy is made inferior and parallel to the piriformis tendon, and then along the posterior femur, detaching the gemelli and obturator insertions en-bloc with the capsule. 2B. Once implants are in place, the capsular repair is performed by advancing the inferior capsular flap 2–3 cm superiorly and repairing to the superior capsular edge. 2C. Capsular repair is performed using heavy, braided, nonabsorbable #5 suture, advancing the inferior capsular flap superiorly as shown. 2D. Final closure showing a tight "noose like" reconstruction of the capsule around the prosthetic femoral neck.

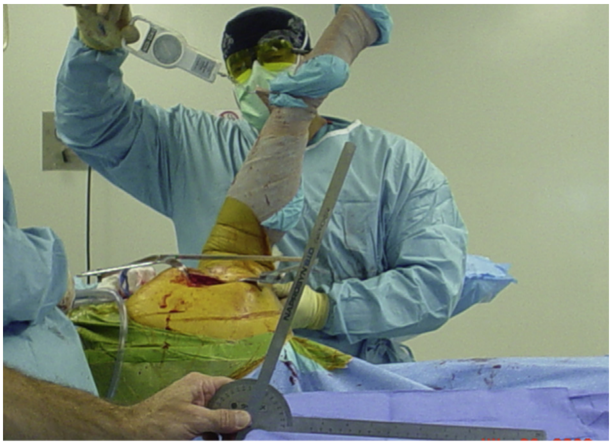

Fig. 3. Testing torque and angular range of motion following capsular repair. A tensiometer is used to measure torque required to dislocate the hip, and the angular measurement to dislocation measured using a goniometer.

types were made using Student's *t*-test between each of the three capsular repair conditions.

Also, this retrospective study is fully compliant with the STROCSS criteria [36].

5. Results

5.1. Part A

Forty six patients (25.7%) in Group 1 and 8 patients (5.3%) in Group 2 were excluded for inadequate follow up leaving 133 patients and 144 in each group for study. Average follow up for Group 1 was 37 months (range 26–47 months) and for Group 2 was 31 months (range 24–89 months). Demographically, there were no significant differences between the two groups.

The demographic details of the patients with their age,gender, laterality, high vs standard offset, diagnosis distribution in the study population (Osteoarthritis/RA/Avascular necrosis/DDH) and average follow up in months is illustrated in Table 1.

Seven patients in Group 1 (5.3%) dislocated at an average of 5.4 months postoperatively (range 0–20 months) and one patient in Group 2 (0.69%) dislocated 5 weeks postoperatively ($p = 0.02$, Table 2). Three of the seven dislocators in Group 1 had a high offset stem while the one dislocation in Group 2 had a standard offset stem.

2 patients (both dislocated posteriorly) in Group 1 underwent immediate revisions for component malpositioning. One patient out of these dislocated in the recovery room underwent immediate revision by repositioning of the acetabular component in less retroversion. The other patient underwent femoral component revision 4 days after the index procedure. All other dislocations in Group 1 were treated initially with closed reduction and bracing for 3–6 weeks.

Two patients, one in each group, developed chronic, recurrent dislocations and required revision surgeries. The recurrent dislocation in the Group 1 patient was posterior and that in Group 2 (the only dislocation in this group) was anterior. This Group 2 patient's dislocation was likely due to excessive anteversion of the acetabular component and was initially treated by closed reduction and bracing. However, after recurrent dislocations, the patient underwent revision of the acetabular component. At final follow-up, neither of these patients have re-dislocated.

5.2. Part B

In the mechanical testing part of the study, 20 hips with an unrepaired joint capsule showed a mean torque resistance at dislocation of 0.68 ± 0.32 Nm (0.069–1.11) and a mean angular range of motion (internal rotation) at dislocation of 49.8 ± 8.2° (35.0°–70.0°).

With classic repair of the joint capsule, the capsule could not be reattached to the greater trochanter in six patients (30%) because the contracted posterior capsule was to short to reach the posterior edge of the greater trochanter. In five of these patients, the posterior capsule was repaired to the posterior border of the gluteus medius tendon. One patient's hip capsule could not be reattached to either the greater trochanter or gluteus medius tendon and, therefore, was not included in the classic repair group. In the remaining 19 patients, the mean torque resistance at dislocation was 0.82 ± 0.34 Nm (0.14–1.52) with a mean angular range of motion at dislocation of 53.6 ± 8.1° (40°–70°).

After capsular noose repair, the mean torque resistance at dislocation was 1.05 ± 0.38 Nm (0.50–1.82) and a mean angular range of motion at dislocation of 66.4 ± 7.6° (55°–90°). The majority of hips tested after capsular noose repair could not be completely dislocated. Many of them could only be partially subluxed with the maximal internal rotation torque applied but would reduce spontaneously with return of the hip to neutral position.

Table 3 gives a detailed account of the P-values when each type of repair has been compared to evaluate existence of a statistical significant difference between the torques of resistance and angular motion in these groups.

Table 1
Patient demographics.

Demographic variable	Classic repair [Group-1] (N = 133 Patients)	Capsular noose [Group-2] (N = 144 Patients)	P-value
Age (mean)	60.1 ± 12 (31–83)*	62.1 ± 11.3 (31–85)	0.24
Gender=			
Males	50 (37.6%)	40 (27.8%)	0.08
Females	83 (62.4%)	104 (72.2%)	
Laterality=			
Left	58 (43.6%)	75 (52.1%)	0.14
Right	75 (56.4%)	69 (47.9%)	
High offset stems	51 (38.3%)	53 (36.8%)	0.909
Diagnosis=			
1.Osteoathritis	105 (78.9%)	119 (82.6%)	0.21
2. Avascular necrosis	18 (13.5%)	20 (13.9%)	
3. DDH	8 (6.1%)	3 (2.1%)	
4. Rheumatoid arthritis	2 (1.5%)	2 (1.4%)	
Average	37 ± 3	31 ± 6	1.03
Follow- up (months)	(Range = 26 to 47)	(Range = 24 to 89)	

Table 2
Dislocation rates.

Groups	Dislocations	P-value
1)Classic Repair (N = 133) (Group-1)	7 (5.3%)	0.02 (statistically significant)
2)Capsular Noose (N = 144) Group-2)	1 (0.69%)	

Table 3
Biomechanical study.

Parameters	No repair	Classic repair	Capsular noose repair	P Value
Torque	0.68 ± 0.32Nm	0.82 ± 0.34Nm		0.12
Angular Range of Motion	49.8 ± 8.2°	53.6 ± 8.1°		0.08
Torque	0.68 ± 0.32 Nm		1.05 ± 0.38Nm	<0.002
Angular Range of Motion	49.8 ± 8.2°		66.4 ± 7.6°	<0.001
Torque		0.82 ± 0.34Nm	1.05 ± 0.38Nm	<0.05
Angular Range of Motion		53.6 ± 8.1°	66.4 ± 7.6°	<0.001

The capsular noose advancement provided a mean 16.6 ± 8.3° additional internal rotation before dislocation when compared with no repair ($p < 0.001$) and a mean 12.8 ± 7.2° additional internal rotation before dislocation when compared with the classic repair ($p < 0.001$). Additionally, the capsular noose advancement provided an additional torque resistance at dislocation of 0.37 ± 0.19 Nm when compared with no repair ($p < 0.002$) and an additional torque resistance at dislocation of 0.23 ± 0.21 Nm when compared with the classic repair ($p < 0.05$).

6. Discussion

The posterior approach to THA allows for excellent and extensile exposure of the hip and is popular among orthopedic surgeons. The senior author and others previously modified the standard posterior approach into an MIS technique that is reproducible and widely applicable [24–26]. However, the orthopedic literature is replete with studies consistently showing a relatively higher risk of postoperative dislocation with the posterior approach as compared to other approaches to the hip [1,12,13].

Some of the studies examined the topic in the context of either a posterior capsulectomy or no repair of the posterior soft-tissue sleeve [7,27]. Several authors also espoused the idea of posterior soft tissue reconstruction to reduce the risk of postoperative dislocation [10,15–19,22]. These authors have achieved a significant decrease in postoperative dislocation rates through repair of the posterior capsule and external rotators to the greater trochanter or gluteus medius tendon. Despite their success with these repairs, Pellici, et al. still noted that their repair may be insufficiently strong to prevent dislocation [10]. In our experience and others', this clasic repair is often difficult to perform and has a high failure rate [23,28,29]. Accordingly, we noted a relatively high dislocation rate of 5.3% in this study.

In a bid to improvise on the classic technique of posterior soft tissue repair in order to offbeat an annoying complication like dislocation from this rather versatile and commonly used posterior MIS approach of THA, there have been various recent recommendations in literature. Modifications to the classical transosseous capsular repair technique like decreasing the diameter of trochanteric drill holes, altering the type of sutures being used, utilization of suture anchors for better capsular suture strength and altering the surgical plane of the Posterior MIS technique have been described.

Osmani et al. [30]suggested reducing the diameter of drills used from 2.7 mm (as used and documented by White et al. [16]) to 2.3 mm for a lower incidence of greater trochanteric fractures (reported to be 0.9% by White et al. [16]) and used 2.0 Fiberwire for their repair. Zhang et al. [31]advocated using suture anchors (TwinFix Ti 5.0, Smith & Nephew, Andover, MA) by making just two 2.3 mm drill holes at the trochanteric crest. Capsular repair by the circumferential "Purse string" technique using 3 mm cottony Dacron suture has been suggested for situations when proximal femoral arthroplasty is done for major tumor resections [32].

Alterations in the surgical plane like using a "superior capsulotomy" approach (leaving the entire posterior capsule and abductors intact) [33] and doing Mini-posterior THA with a "transpiriformis" approach [34] have been evaluated for making the posterior approach less amenable to dislocations. Recently, changes in the suture type (usage of barbed and knotless sutures) have also been proposed in literature for a watertight robust closure of not only deep structures (capsule) but all layers of the tissue [35].

Our study is a prototype study proposing changes just in the approximation technique to increase the strength and resistance of the sutured posterior capsular cuff and decreasing postoperative dislocation. It does not have a learning curve to it and there is no plane alteration to the streamlined posterior approach. There is no extra step of drilling trochanteric holes and the technique can be accomplished by the routinely used & cost-effective Ethibond #5.

This study demonstrates a statistically significant decrease in postoperative dislocation rate with use of the capsular noose repair. Utilizing this technique, the dislocation rate with the posterior approach rivals that for the direct lateral, anterolateral, and direct anterior approaches [1,7,12,27].

The mechanical stability provided by the capsular noose repair appears to account for the reduced dislocation rate. This technique greatly enhances both internal rotation and torque resistance to dislocation when compared with no repair of the posterior soft tissues and with the classically described transosseous repair. The finding of increased internal rotation before dislocation is noteworthy. White et al. argued that the transosseous repair acts as a check-rein against dislocation, primarily by decreasing internal rotation; and they partially attributed their success of decreased dislocation rate to restriction in internal rotation by almost 50% [16]. The transosseous repair also leaves considerable dead space posteroinferiorly, so that the hip will easily dislocate if the femoral head is levered out of the acetabulum in flexion. The capsular noose repair closes this dead space, tightening the capsule around the neck of the prosthetic femoral component similar to a noose around a neck. This allows for excellent protection against dislocation by reconstructing the posterior tension band effect of the capsule, while still permitting more internal rotation than the transosseous repair can provide. Additionally, the authors suspect that when the hip begins to lever out in flexion, tension on the posterior capsule may cause pain, which may lead the patient to reposition the limb. Thus, a physiologic mechanism may reinforce the purely mechanical restraint.

Advancing the posterior capsule and external rotators as a flap to the superior capsule provides for a solid, posterior capsular repair that effectively reduces the risk of dislocation while maintaining range of motion. We now utilize this repair on all of our primary total hip arthroplasty patients without difficulty since the last 15 years. In addition, we also use this repair in revisions where sufficient posterior soft tissue remains for closure. Maintenance of the piriformis insertion to the greater trochanter, while not critical to this technique, may add additional posterior stability and external rotation strength without the risk of pull-off in the postoperative period.

Limitations of this study deserve comment. Although we made all efforts to standardize our populations, several different total hip designs and brands were used, although all hips utilized 28 mm heads and acetabular liners with elevated rims. We did not evaluate leg lengths or offsets to see if these factors could have contributed to dislocations in either group. Additionally, both groups had roughly equal ratios of standard to high offset stems. We also do not know how many of the Group 1 patients had a transosseous repair versus a repair to the gluteus medius tendon. Lastly, our mechanical study did not provide an exact reproduction of the transosseous repair, because we simulated it using towel clips through the capsule and trochanter, rather than sutures; and several hip capsules could not be reattached to bone, therefore were repaired to gluteus medius tendon. Nonetheless, we believe that we achieved a fair reproduction of its biomechanical properties and established a sound starting point for further biomechanical studies. Better studies, such as the cadaveric biomechanical studies by Sioen et al. [8] are needed to validate these findings and shed further light on this comparison.

7. Conclusion

The capsular noose advancement repair significantly reduces the incidence of dislocation after posterior-approach total hip arthroplasty. It provides both a physiologic and mechanical restraint to dislocation that appears superior to that provided by the more traditional posterior soft-tissue repair techniques. This technique promises to drastically reduce the historically troublesome dislocation rate associated with the posterior approach.

Ethical approval

Not applicable as this is a capsular closure technique description.

Funding

No.

Author contribution

Todd V. Swanson, M.D. - Senior surgeon,Study design,Manuscript writing and final edits.

Mohit M.Kukreja, M.D. – Literature search,Manuscript writing,final corrections

James C. Ballard, M.D. - Manuscript writing,Part B study,Data collection and compilation.

Henry G. M. Calleja – Data collection,tabulation,Manuscript writing.

Jonathon M. Brown, B.S. – Tables and Data analysis,Literature search.

Conflict of interest

No.

Guarantor

Dr Mohit M Kukreja.

Research registration number

4595.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijso.2018.12.005.

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