JOURNAL OF ARTHROSCOPY AND JOINT SURGERY

JAJS

Official Journal of the International Society for Knowledge for Surgeons on Arthroscopy and Arthroplasty (ISKSAA)

Indexed in Scopus & Embase

Volume 9 | Issue 2 | April-June 2022

ISSN: 2542-6001

Wolters Kluwer

https://journals.lww.com/jajs

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Journal of Arthroscopy and Joint Surgery

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Journal of Arthroscopy and Joint Surgery (JAJS) is an official, peer reviewed, online scientific journal. The first edition of which rolled out in January 2014. The journal's full text is available online at https://journals.lww.com/jajs and issues are published quarterly in March, June, September, December. The Journal is committed to bring forth scientific manuscripts in the form of original research articles, current concept reviews, meta-analyses, case reports with a clear message and letters to the editor.

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Published by
Wolters Kluwer India Private Limited,
A-202, 2nd Floor, The Qube, C.T.S. No.1498A/2 Village Marol,
Andheri (East), Mumbai - 400 059, India.
Phone: 91-22-66491818
Website: www.medknow.com

Printed at
Nikeda Art Printers Pvt. Ltd.,
Building No. C/3 - 14,15,16,
Shree Balaji Complex, Vehele Road,
Village Bhatale, Taluka Bhiwandi,
District Thane - 421302, Mumbai, India.

Journal of Arthroscopy and Joint Surgery

Volume 9 | Issue 2 | April-June 2022

Contents

Original Articles

Technical Note


Reject
Accept

Sagittal Pelvic Tilt Change after Total Hip Arthroplasty: An Evaluation using Supine Frontal Pelvic Radiographs

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Abstract

Purpose: Pelvic tilt (PT) affects acetabular orientation which in turn influences the outcome after total hip arthroplasty. Calculating sagittal PT using parameter measured on frontal supine pelvic radiograph can increase ease of its recognition, quantification, and potentially predict change. **Materials and Methods:** In this retrospective study of 80 patients, who underwent unilateral THA for primary osteoarthritis, PT was calculated from standard supine frontal pelvic radiographs preoperatively and its change at 1 year follow-up. This was analyzed and correlated with published literature which utilized standing lateral pelvic radiographs. **Results:** The majority of our patients had change in the PT which correlated well with other studies which use standing lateral radiographs. One-fourth of them had more than 10° change in the PT at 1-year postoperative. **Conclusion:** The technique is easy and reproducible. Larger studies are needed to analyze the subgroups, especially "supertilters" and prescribe tilt correction.

Keywords: Frontal pelvic radiograph, pelvic tilt, total hip arthroplasty

Introduction

Acetabular cup positioning affects outcome after total hip arthroplasty and is essential to prevent complications such as component malposition, impingement pain, accelerated bearing surface wear, and dislocation.[1-5] Pelvis is a dynamic link between axial and appendicular skeleton and it is well known that changes in pelvic tilt (PT) affect acetabular orientation. Various studies have shown that most patients who undergo total hip arthroplasty have some degree of PT resulting in change of pelvic orientation.[1,4,6,7] Some studies have even quantified that each degree of PT resulted in change of acetabular anteversion by 0.7°.[8,9] Therefore, prediction of change in PT change preoperatively can equip us to achieve better cup orientation and achieve good functional outcome in total hip replacements.[2,4]

Unfortunately, the frequency and extent of postoperative change in the PT following total hip arthroplasty are conflicting in the literature and the results are variable.[1,4,5,10] Moreover, the evaluation of the PT typically has been done in standing lateral pelvic radiographs.[1,2,4] This is not routinely performed in the preoperative or postoperative evaluation of patients undergoing total hip arthroplasty. The positioning of the patient for lateral pelvic radiograph can be challenging and it also exposes the patient to increased radiation. There are only few published studies in the literature which have attempted to calculate PT from frontal pelvic radiographs.[11-13] The purpose of this study is to calculate the PT from standard supine frontal pelvic radiographs in a patient cohort of primary hip osteoarthritis (OA), undergoing primary unilateral total hip arthroplasty and to compare the changes in the PT at 1-year follow-up using the same view. We posed the following questions:

1. Is there a consistent change in PT following total hip arthroplasty?
2. If so, does it correlate with the changes that are reported in the literature which utilized standing lateral pelvic radiographs?

Access this article online	
Quick Response Code:	**Website:** https://journals.lww.com/jajs
	DOI: 10.4103/jajs.jajs_13_22

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Submitted: 08-Feb-2022 **Revised:** 04-Apr-2022
Accepted: 14-May-2022 **Published:** 14-Sep-2022

How to cite this article: Deep K, Sameer MM, Shah SM. Sagittal pelvic tilt change after total hip arthroplasty: An evaluation using supine frontal pelvic radiographs. J Arthrosc Jt Surg 2022;9:47-50.

3. Is there a correlation between gender and BMI with preoperative and postoperative change in PT?

Materials and Methods

Study design

This was a retrospective study performed after approval by the institutional review committee. One hundred and one consecutive patients who underwent total hip arthroplasty for unilateral primary OA without previous history of spinal pathology were considered in this study. Inclusion criteria included the presence of standardized supine frontal pelvic radiographs both preoperative and 1-year postoperative follow-up period. All images were taken with standard source-to-image distance with the beam directed to the pubic symphysis to visualize sacrum pelvis, femoral heads, and proximal one-fourth of femur with neutral rotation. Twenty-one patients who had obscured anatomical landmarks such as gas shadows either in the preoperative or a postoperative X-ray were excluded from the study. This left us with 80 patients and 160 radiographs for analysis. There were 40 males and 40 females. The mean age at surgery was 68.4 years (range 44–92 years).

Analysis

The vertical distance between the upper edge of the pubic symphysis and the middle of the sacrococcygeal joint was measured for all patients in both preoperative and 1-year postoperative follow-up radiographs using the standard PACS software [Figures 1 and 2]. This measurement was chosen as it was the only parameter from the supine AP pelvic radiographs which had moderately strong correlation with PT (angle between horizontal and line connecting the pubic symphysis with sacral promontory) by Tannast *et al*.[11] The authors have derived a nomogram for the calculation of the sagittal PT from this parameter with reasonable accuracy. This was used in this study by incorporating in our spreadsheet (Microsoft Excel).

All measurements were performed by a single person after correcting for intra-observer reliability. The calculation and statistical analysis were performed using SPSS Software. Subgroup analysis was performed to assess the change in male and female patient groups and to a analyze extent of change in anterior and posterior pelvic tilters.

Results

The mean change in the PT in the whole group was 5.5° (absolute) ±5.1°. Males had a mean change of 5° (absolute) ±4.8° and females had a mean change of 6.1° (absolute) ±5.4°. On subgroup analysis, 55 patients had a posterior postoperative PT of about 6.6° ±5.6° (range from 0.2° to 20.5°) and 24 patients had anterior postoperative PT of 3.5° ±2.9° (range from 0.3° to 8.3°). One patient had no change in the postoperative PT. Nineteen patients (24%) had more than 10° change in the PT at 1-year postoperative and all of them were posterior tilters. There is no reversal of PT in the group of patients studied.

The data were analyzed with IBM SPSS statistics software. Paired Samples *t*-test revealed that there is a significant change of PT before and after surgery ($P = 0.0005$) but no correlation between BMI and change in the PT. Further, there is no significant difference in the change of PT between the genders by Independent Samples t-test. Regression model analysis shows that there is no influence of postoperative PT with BMI ($P = 0.324$), age ($P = 0.877$), and gender ($P = 0.219$), but there is significant influence with preoperative PT ($P = 0.0005$).

Discussion

There has been a renewed interest in the effect of spinopelvic indices such as PT on the functional outcome after total hip arthroplasty, particularly with the recent development of navigation and robotic-assisted hip replacements.[14,15] Preoperative pelvic radiographs for planning the cup inclination

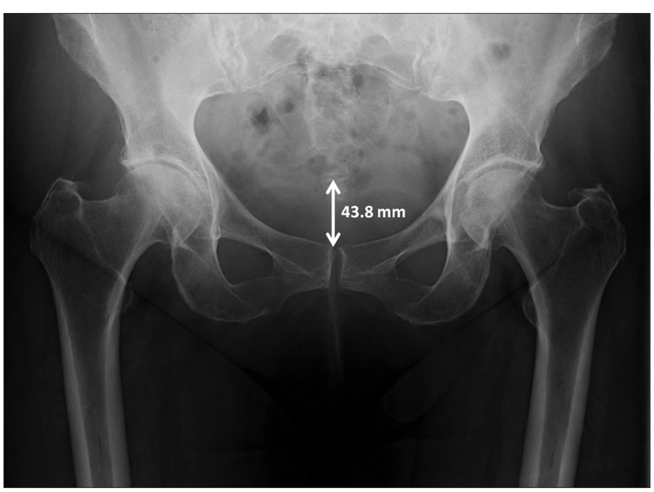

Figure 1: Preoperative pelvic tilt in a 66/F patient derived from measuring vertical distance between the upper edge of symphysis pubis and the mid of the sacrococcygeal joint

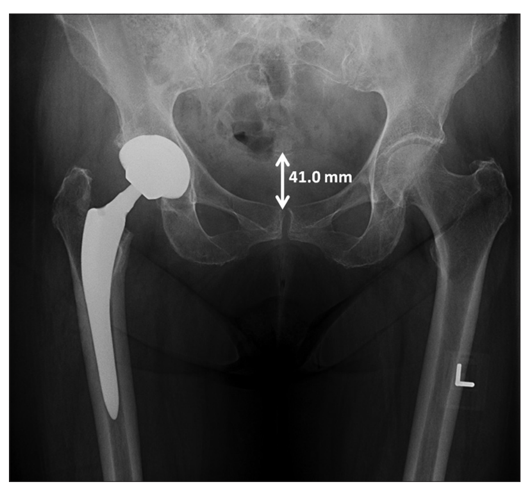

Figure 2: One-year postoperative pelvic tilt (posterior) in the same patient derived from measuring vertical distance between the upper edge of symphysis pubis and the mid of the sacrococcygeal joint

and anteversion use the coronal axis for reference whereas intraoperatively, methods for appropriate cup position rely on the anterior pelvic plane or anatomical landmarks as reference points both of which vary with PT.[16] Furthermore, changes in the PT in supine and standing positions and range of displacement after surgery can further confound the orientation of the cup. Experts agree to evaluate PT during preoperative assessment and to feed in the required adjustments during surgery which can potentially avoid the "unexplained pain," impingement and "safe zone dislocations" after total hip arthroplasty and thereby lead to superior functional outcome.[4,5,15,17]

However, there is no one convenient solution at present. This is partly because of availability, difficulty, and variability of assessing PT by lateral spinopelvic radiographs and the controversy regarding the range and frequency of change after surgery. A simple and a reasonably accurate method to calculate PT from standard supine frontal pelvic radiographs regularly done during the preoperative assessment will greatly enhance the surgeons' ability to quantify PT, assess and record its change after surgery with ease, prescribe, and follow recommended adjustments during surgery if needed. We chose to measure a surrogate marker to calculate the PT from standard supine frontal pelvic radiographs, because of its simplicity, availability, and minimal expense associated with acquiring these images and the fact it is most commonly done radiograph before surgery and during follow-up.[11]

We set out to find whether the PT as calculated from standard supine frontal pelvic radiograph changes after surgery and whether it correlates with the published literature. We found that the PT changed in almost all of our patients except one and approximately one-fourth of our patients (24%) had more than 10° of change at 1-year follow-up. This is in accordance with most of the published studies which had utilized standing lateral pelvic radiographs to measure the change in PT after surgery.[4,7,8,10,18,19] To the best of our knowledge, there are only two previous studies which had calculated PT from supine frontal pelvic radiographs.[13,19] Both their findings were also similar to our study although they have utilized Sacro-Femoral-Pubic parameter (SFP) from frontal pelvic radiographs to calculate the sagittal pelvis tilt.

Majority of our patients (76%) had minimal change in the PT. The mean change in the PT was 5.5° (absolute) ±5.1°. This is also similar to other published studies,[1,6,7,10] the only difference being the proportion of patients who had more than 10° of PT was higher in our study. Furthermore, BMI, age, and gender do not seem to affect the change in PT after surgery in our study. The presence of preoperative PT in our patients is significantly correlated with the frequency of postoperative PT. This is consistent with other studies which had utilized standing lateral pelvic radiographs to measure the change in PT after surgery.[4,6,8]

At least 24% of our patients had more than 10° of change in PT and all of them were posterior tilters. This was 0% in the study by Blondel *et al*.,[6] 7% in the study by Shah *et al*.[10] and 17% in the study by Ishida *et al*.[1] We hypothesize that this is due to the advanced OA in our patient group where there is a relatively forward-tilted pelvis during preoperative state and they all develop an adaptive backward tilt after the surgery when the flexion contracture disappears. This is evident by the fact that we had more posterior tilters than anterior tilters. If we apply the findings of Lembach *et al*.,[8] this subgroup of our patients, they are likely to have a change in cup anteversion of more than 7° at 1 year due to this change in the PT. In patients with "greyzone position" of the cup, this postoperative change can potentially add on to cause a subtle acetabular malorientation which in turn can lead to edge loading, bearing surface wear and "unexplained pain" if not frank dislocation. Further studies are required to define this subset of "supertilters," who have more than 10° of posterior postoperative PT after surgery so that they can benefit from tilt adjustment of the component position during surgery.

The present study has several limitations. We measured sacrococcygeal joint to pubic symphysis distance described by Tannast *et al*.[11] as the surrogate marker even though it had moderately strong correlation with sagittal PT from lateral pelvic radiograph. However, this parameter had the best correlation among the other available validated parameters,[11,13] was easy to measure and calculate from routine radiographs without requiring special projections and increased radiation.

We did not have the record of range of motion of the affected hip in all our patients to correlate with possible flexion contracture and the change in PT. However, we have included only patients with advanced primary OA of hip without a history of spine pathology which is representative of patients undergoing surgery in our center. Hence, the assumption that the tilt is due to stiffness of hips rather than spinal pathology. Moreover, the range of motion evaluated in clinic could be variable, subjective, and inaccurate.

Finally, we assessed postoperative PT in one plane (frontal), in one position (supine), and in one follow-up (1 year) interval. Studies have shown changes in the PT starting from 6 weeks following surgery and that changes in the functional position such as standing maybe more representative.[15,18,20] Furthermore, more accurate correlation and validation of PT could have been achieved if lateral radiographs were also taken in the same patient population. While we agree that this can be done to improve accuracy, incorporating this into our model would defeat the purpose of simplicity and clinical applicability. We also propose to design further studies incorporating the same and along with patient satisfaction and PROMs to analyze the effect of change in PT on the functional outcomes after total hip arthroplasty.

Conclusion

The PT changes after total hip replacement surgery. Standard supine frontal pelvic radiograph can be used to calculate the sagittal PT before and after surgery as the findings correlate well with studies using lateral spinopelvic projection. Larger studies are needed to analyze the subgroups especially the "supertilters," to predict the change and prescribe correction.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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A Prospective Observational Study on Short-term Functional Outcomes of Primary Reverse Shoulder Arthroplasty in the Indian Population

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Abstract

Background: Reverse shoulder arthroplasty (RSA) is becoming more popular for specific indications globally with good functional outcomes reported. There is no study, to the authors' knowledge, on the outcomes of RSA in the Indian population. The present study aimed to fill the void. **Methodology:** A prospective observational study on the functional outcomes using University of California, Los Angeles (UCLA) and Constant scores in the first 27 consecutive patients who underwent RSA in a tertiary care hospital between 2019 and 2020 were assessed in periodic intervals up to a maximum of 1-year follow-up. **Results:** Twenty-seven patients underwent unilateral primary RSA and were included with a median age of 71 years (interquartile range [IQR]: 66–76). There was a statistically significant improvement in both the functional scores over the study duration. At a follow-up time of 6 months ($n = 27$ patients), the median improvement in UCLA score was 17 points (IQR: 12–19) and Constant shoulder score of 52 points (IQR: 47–60). Thirteen of these patients were followed up further up to 1 year, with a median improvement in UCLA score of 13 points (IQR: 21–25) and Constant shoulder score of 56 points (IQR: 49.50–66.50) from the preoperative scores. All 27 implants were radiographically stable. There was 7.4% complication rate; one scapular notching was noticed at the end of 1-year follow-up and one glenosphere dissociation in the immediate postoperative period. **Conclusion:** RSA provides consistent improvements in functional outcome measures in the Indian population with a low complication rate. Further studies with larger patient cohorts and longer follow-ups are needed to validate these findings.

Keywords: Constant score, glenosphere dissociation, Indian population, prospective observational study, scapula notching, short-term functional outcome, statistically significant, unilateral, University of California, Los Angeles

Introduction

The shoulder joint is the third most commonly replaced joint in the body after the hip and knee joints.[1] In the current scenario, reverse shoulder arthroplasty (RSA) has become an essential tool in the armamentarium of shoulder surgeons. The original indication was primarily the low-demand elderly patient with rotator cuff arthropathy. The design of the RSA has improved substantially in the last decade as it relates to prior clinical limitations and this has enabled the surgeons to expand the indications to include even relatively younger patients with cuff arthropathy, primary glenohumeral arthritis, inflammatory shoulder arthropathy, comminuted proximal humerus fractures not amenable to surgical fixation, massive cuff tears without cuff tear arthropathy, and revision of a failed total shoulder arthroplasty.

RSA has become an increasingly popular surgery among orthopedic surgeons in the United States, since the Food and Drug Administration approved it in 2004, and as of now, it has surpassed anatomic total shoulder arthroplasty in numbers.[2] However, in an Indian setup, the same enthusiasm is not evident for RSA and it remains an underutilized surgery due to various reasons. One of the salient reasons is the lack of

Access this article online
Quick Response Code:
Website: https://journals.lww.com/jajs
DOI: 10.4103/jajs.jajs_37_22

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Submitted: 23-Feb-2022 **Revised:** 06-Jun-2022
Accepted: 24-Jun-2022 **Published:** 14-Sep-2022

How to cite this article: Chitten JJ, Arora M, Bathla G. A prospective observational study on short-term functional outcomes of primary reverse shoulder arthroplasty in the Indian population. J Arthrosc Jt Surg 2022;9:51-6.

available data specific to our population, which guides clinical decision-making for the surgeon and the patient. *In lieu* of this, the present study aimed to provide the first functional outcome data of RSA specific to the Indian population.

Methodology

A prospective observational study was conducted in a tertiary care hospital after receiving approval from the hospital institutional review board. We aimed to analyze the functional outcomes and complications of RSA in short-term follow-up.

Patients

We included the first 27 consecutive patients who underwent reverse total shoulder arthroplasty between 2019 and 2020 with a minimum of 6-month follow-up. All the surgeries were done by a single senior shoulder surgeon. All the patients gave their written informed consent to participate in this study. In all the patients, the index surgery was indicated based on careful preoperative clinical and radiological assessment using plain radiographs, computed tomography, and magnetic resonance imaging.

Inclusion criteria

1. Irreparable massive rotator cuff tears
2. Glenohumeral arthritis (Samilson and Prieto Stage III)
3. Comminuted proximal humerus fractures not amenable to surgical fixation
4. Failed rotator cuff repair
5. Avascular necrosis (AVN) of the humeral head.

Exclusion criteria

1. Infected shoulder
2. Patients not fit for surgery
3. Lack of written informed consent
4. Neuropathic shoulder joint
5. Deltoid insufficiency (MRC grading <IV)
6. Axillary nerve palsy.

All the patients were recruited into the study after institutional ethical clearance. The patients signed written valid informed consent before study participation. Preoperative baseline data were obtained for all patients including demographic factors (age and gender), duration of symptoms, any episode of injury, and clinical data (shoulder examination and functional outcome measures). Functional outcome was assessed before surgery using two validated instruments: Constant–Murley (Constant) and University of California, Los Angeles (UCLA) shoulder scores. The severity of the pathology was graded using Samilson–Prieto classification and the glenoid status was assessed using Walch classification and Favard classifications. Postoperatively, patients were followed up at regular intervals of 6 weeks, 3 months, 6 months, and 1 year. We included the patients with a minimum of 6-month follow-up and a maximum of 1-year follow-up. Clinical assessment with functional outcome measure scoring and radiological assessment using plain radiograph with Grashey's view was performed at each visit, and any potential complications (such as pain, stiffness, infection, and dislocation/subluxations) were noted. Data collection was carried out by the first and the third authors, and the surgeon was blinded to outcome scoring throughout the study. Clinical assessment was performed by all the authors.

Surgical technique

All surgical procedures were performed by the senior author using comprehensive reverse shoulder system (Fa. Zimmer-Biomet, Warsaw, IN, USA). The procedure was done with the patient in the beach chair position and under general anesthesia with an interscalene block. The standard deltopectoral approach was used for the exposure in all the patients. A skin incision was made over the deltopectoral interval beginning from just lateral to the coracoid tip. The cephalic vein was preserved and retracted laterally along with the deltoid and the coracobrachialis conjoined tendon retracted medially. The long head of the biceps tendon was tenodesed at the level of the pectoralis tendon. Anterior circumflex vessels were identified at the inferior border of the subscapularis tendon and ligated. Any remaining subscapularis tendon was detached from the lesser tuberosity and was tagged for reattachment at the end of the procedure, if amenable.

Next, the joint capsule was circumferentially released and humeral head was exposed. The starting 5-mm entry reamer was entered just superior to be passed through the humerus intramedullary canal to perform a humeral head osteotomy. The humeral head was then reamed and broached. Subsequently, the glenoid was exposed, the labrum was excised, and the glenoid was prepared.

The guidewire for the glenoid reamer was placed 10° inferiorly, so that the glenoid baseplate will be flush with the inferior border of the native glenoid rim perpendicular to the line of the floor of the supraspinatus fossa. This will help decrease the risk of scapular notching. A cannulated baseplate reamer was used to abrade the glenoid until the subchondral plate was reached, which is typically at a depth of approximately 2–5 mm. By adding inferior tilt to the position of the baseplate, the risk of scapular notching can be decreased, which, in turn, improves compressive forces and helps avoid shear forces on the glenoid component. The baseplate was impacted in place and secured with screws to securely fix the baseplate to the patient's native glenoid. The selected glenosphere was then secured to the baseplate with a Morse taper fixation mechanism. The selection of the appropriately sized glenosphere was multifactorial. It was based on the patient's size (i.e., 42 mm for larger patients, 39 mm for average size patients, and 36 mm for smaller patients) and individual patient pathologies. Glenosphere components were available in central, lateral offset, and inferior offset designs. A +3-mm lateral offset liner was used as a standard for all implants, with variations made for intraoperative findings.

Next, the humeral stem was prepared by sounding the inner diameter of the humeral shaft and broaching it to the appropriate size. The final implant was tested with the spacer trials to gain proper stability and range of motion. Then, the definitive implants were seated in a cementless manner and the shoulder was reduced. All the patients received a mini-stem except for the three patients with fracture of proximal humerus for whom we used standard stems. Then, the subscapularis was reattached to the lesser tuberosity insertion with 1-0 Ethibond, piercing the bone with the attached needle itself as all these patients had relatively osteoporotic or osteopenic bone quality. Incase if subscapularis was not amenable for repair, we left it unrepaired. The deltopectoral interval was reapproximated, and the incision was closed in layers. The patient was placed in a shoulder immobilizer for a period of 2 weeks with a home physical therapy program. At 2-week follow-up, the patient was removed from a shoulder immobilizer, stitches were removed, and a more aggressive rehabilitation program begun, which progresses for 3 months postsurgery.

Statistical analysis

Statistical analysis was done using GraphPad Prism 9.0.0 (California, USA). Continuous data were summarized as median and interquartile range (IQR) and categorical data as percentages. Shapiro–Wilk test was used to test for normality of continuous data. The median values for baseline and postoperative data were compared using the Wilcoxon matched-pairs signed-rank test. Improvement in scores was compared between the groups using Wilcoxon rank-sum test.

Results

Patient demographics

Twenty-seven patients were included in the study. The median age at surgery was 71 years (range, 55–78), out of which the majority (n = 14) were above 70 years of age. The majority of the study participants were female (74%), and right shoulder surgeries (65.6%) were done more frequently than the left side (44.4%) [Table 1].

Eighteen (66.7%) patients had irreparable massive rotator cuff tears with severe glenohumeral arthritis, and five patients had irreparable massive rotator cuff tear with moderate glenohumeral arthritis, out of which one was failed prior rotator cuff repair. Three patients presented with nonsalvageable fracture dislocation of the shoulder and one patient had AVN of humeral head with severe glenohumeral arthritis. According to the Favard classification, there were 3 E0, 14 E1, 8 E2, 1 E3, and 1 E4 glenoid, and according to Walch classification, there were 1 A0, 14 E1, 3 A2, 5 B1, and 4 B2 glenoid. The median preoperative TSA angle was 20.05 (IQR: 17.34–26.84), with the least recorded angle being 13.34 and the maximum being 29.85. The median preoperative CSA angle was 35.34 (IQR: 31.78–37.74), with the least angle recorded being 24.60 and the maximum being 43.24.

Table 1: Baseline characteristics

	Median (IQR) or *n* (%)
Age	
55-78 (range)	71.0 (66.00-76.0)
≤70	13
>70	14
Gender	
Females	20 (74)
Males	7 (26)
Side	
Right	15 (65.6)
Left	12 (44.4)

IQR: Interquartile range

Objective outcomes

There was a statistically significant improvement from baseline in UCLA and Constant scores of all the 27 patients at 6 weeks, 3 months, and 6 months of follow-up when compared to corresponding preoperative scores [Tables 2 and 3].

Preoperatively all the patients had unsatisfactory function as per UCLA scores. 14% had excellent outcomes at 6 weeks, 40.7% at 3 months, and 81% at 6 months, and all the patients who followed up for 1 year had excellent outcomes, showing a statistically significant serial improvement in the follow-up duration.

Constant score data [Table 3] showed serial and significant improvements at each follow-up interval compared to baseline values. Both the UCLA and Constant outcomes showed the fastest rate of improvement from baseline data at 6 weeks postoperatively [Graphs 1 and 2] followed by a slower rate of improvement thereafter.

UCLA and Constant score changes at 6 months compared to baseline data showed no statistically significant difference with respect to age (arbitrary age limit of above and below 70 years of age), gender (male versus female), CSA angle (high versus low; >35° vs. <35°), or RSA angle (>20° vs. <20°) [Table 4].

Subgroup analysis for pathologies (cuff tears versus fractures versus OA) was not possible due to low power.

Discussion

The number and indications for reverse shoulder arthroplasties (RSA) are gradually on a rise. The most common indications are osteoarthritis (45%), followed by rotator cuff arthropathy (35%) and fracture (15%).[3] In our study, we noted that majority of the pathology were irreparable massive rotator cuff tears with arthropathy (70.4%), 18.5% were osteoarthritis, and 11.1% were fractures.

40% the patients included in this study had irreparable rotator cuff tear with glenohumeral arthropathy. Rotator cuff dysfunction with or without glenohumeral arthritis is believed to be the best indication for RSA with regard to clinical outcomes and provides pain relief with improvement in shoulder function and thus quality of life.[4-10]

The principal findings in our study were that 81% of the patients achieved excellent outcomes at 6-month follow-up and all the patients who had 1-year follow-up showed excellent outcomes. Both the functional scores indicate that there was a significant

Table 2: University of California, Los Angeles scores

	Score, median (IQR)	Median and 98% CI of improvement from baseline scores	Comparison with baseline, *P* (Wilcoxon matched-pairs signed-rank test)
Baseline	12.00 (9.00-14.00)		
6 weeks	23.00 (21.00-25.00)	13.0 (8.0-15.0)	<0.0001
3 months	26.00 (24.00-28.00)	16.00 (13.00-17.00)	<0.0001
6 months	30.00 (28.00-33.00)	20.00 (16.00-22.00)	<0.0001
1 year (*n*=13)	34.00 (31.00-34.00)	22.00 (17.00-25.00)	0.0002

IQR: Interquartile range, CI: Confidence interval

Table 3: Constant-Murley scores

	Score, median (IQR)	Median, 98% CI of change from baseline median and 98% CI of improvement from baseline scores	Comparison with baseline, *P* (Wilcoxon matched-pairs signed-rank test)
Baseline	22.00 (19.00-32.00)		
6 weeks	64.00 (55.00-66.00)	33.00 (28.00-43.00)	<0.0001
3 months	69.00 (59.00-75.00)	45.00 (38.00-50.00)	<0.0001
6 months	79.00 (69.00-86.00)	54.00 (48.00-60.00)	<0.0001
1 year (*n*=13)	87.00 (78.00-91.00)	57.00 (49.00-66.00)	0.0002

IQR: Interquartile range, CI: Confidence interval

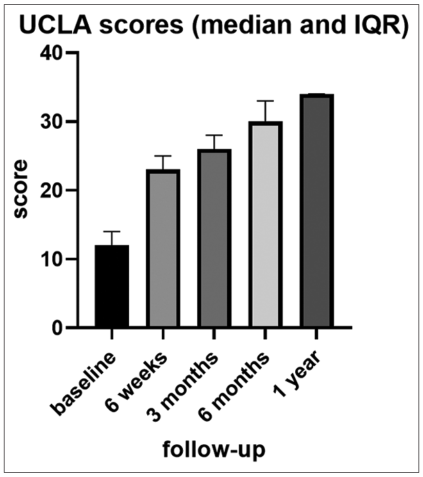
Table 4: Effect of age, gender, and critical shoulder angle on improvement in scores

	n (%)	Difference between scores preoperatively and at 6-month follow-up* (IQR)		*P*
		UCLA	Constant	
Age (years)				
<70	13 (48)	17 (10.5-18.5)	54.00 (50-63.75)	UCLA: 0.3914
>70	14 (52)	17.50 (12.75-19.25)	49.00 (45.0-58.5)	Constant: 0.2667
Female	20 (74)	16.00 (13-19.00)	52.10 (45.5-60.0)	UCLA: 0.8265
Male	7 (26)	17.00 (12.00-19.00)	52.00 (50.00-63.00)	Constant: 0.4533
High CSA angle	14 (51.8)	17.00 (12-19)	52 (46.5-60.75)	UCLA: <0.9905
Normal/low CSA angle	13 (48.2)	16.00 (13-19)	52 (49-61.5)	Constant: 0.6070
RSA angle (°)				
>20	15	17 (13-19)	56 (48-66)	UCLA: 0.8183
<20	12	16.5 (12-19)	50 (45.5-59)	Constant: 0.1937

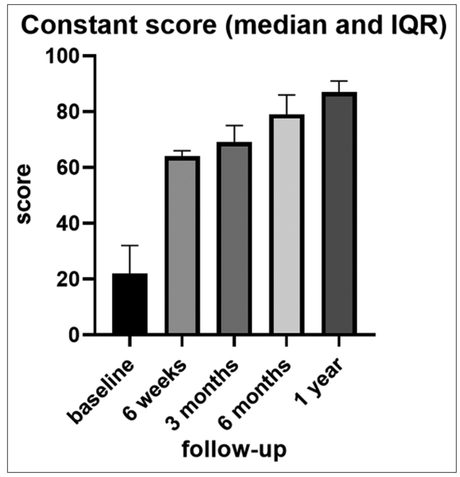
*Median (IQR), †Wilcoxon rank-sum test. CSA: Critical shoulder angle, IQR: Interquartile range, RSA: Reverse shoulder arthroplasty, UCLA: University of California, Los Angeles

pain relief with functional improvement and patient satisfaction at the end of 6 weeks postoperatively and then a steady but relatively a slower rate of improvement in the following assessments. These outcomes are similar to the previous studies. In 2015, Simovitch *et al*. noted in their study that majority of improvement occurred within the first 6 weeks and near full improvement in the 12–24-month range.[11] The concept of rapid improvement during the first 6 weeks with plateau at 12 months was also reported by Müller *et al*. in 2017.[12] The above data also signified that the best patient recovery for pain and function measures is obtained in the first 6 weeks of surgery and thereafter will only show a steady improvement at a gradual pace. Similarly, Seebauer *et al*. noted a 98% satisfaction rate in patients with short-term follow-up after RSA for cuff tear arthropathy, proving the fast recovery of these patients.[13]

For primary RSA, the complication rates in the literature range from 13% to 25%.[14-16] Scapular notching is by far the most common complication during the first 24 months postoperatively. Scapular notching has an incidence of 38%, 57%, 55%, and 73% in four recent studies, respectively.[17-20] In our study, we had one case of Grade II notching (3.7%) noted at 1-year follow-up and an overall complication rate of 7.4% with another patient having immediate postoperative glenosphere dissociation from the baseplate, which required a revision surgery (3.7%) on the same day. The low rate of scapular notching in our study may be due to surgical technique, implant selection, or low sample size. The selection of lateral offset implants for the humeral side as in our study has been theorized to decrease the risk of scapular notching. In 2014, Feeley *et al*. observed that decreasing the neck-shaft angle or a higher inclination angle and 3 mm lateral offset of the glenosphere prosthesis decreased the rate of scapular notching by 16%.[20] We used a +3-mm lateral offset liner as a standard for all implants, with variations made for intraoperative findings. Furthermore, Jarett *et al*. asserted the importance of adding



Graph 1: UCLA median and IQR scores in graph format over study duration. UCLA: University of California, Los Angeles, IQR: Interquartile range



Graph 2: Constant median and IQR scores in graph format over study duration. IQR: Interquartile range

inferior placement of the glenosphere as the most important factor in avoiding inferior impingement.[21] In our patients, we were careful in following these essential steps and therefore we believed that we had a lesser incidence of scapula notching than the existing literature. In addition, Feeley *et al*. observed that of all the patients who did not experience scapular notching during the first 12 months (84% of patients) showed no new evidence of scapular notching during follow-ups up to 30 months.[20] Hence, we expect not further deterioration in this particular patient.

In the current study, all the patients had their subscapularis repaired back at the end of the procedure and none had any instability in the postoperative follow-up. Friedman *et al*. showed that there was no significant statistical difference in outcomes between repaired subscapularis group and unrepaired subscapularis group. However, though not statistically significant, in their study, 340 patients with RSA plus repair had 0% dislocation rate versus 251 patients with RTSA without repair showing a 1.2% dislocation rate.[22] In our study, we found a 0% dislocation rate with repairs of the subscapularis.

For elderly patients with complex fractures, the treatment of choice has traditionally been HA, which has inconsistent results secondary to tuberosity healing and fixation.[23] However, for proximal humerus osteoporotic fractures or complex fractures in elderly patients, there is mounting evidence that RSA is a promising alternative to conventional treatments and its use in this population is supported by current literature.[24-26] Healing of the fractured tuberosity dramatically impacts outcomes for HA, and in the elderly patient population, medical comorbidities frequently predispose to nonunion of the tuberosities.[27,28] Bufquin *et al*. presented mid-term results (mean 22 months) for 43 three- and four-part proximal humerus fractures treated with RSA and noted a significant pain relief with satisfactory functional outcomes compared to HA.[25] These findings were replicated by a prospective, randomized controlled Level 1 study done by Sebastiá-Forcada *et al*. as well as studies by Cuff and Pupello in a 2013 and study by Grubhofer *et al.* in 2016.[26,29,30] In our study, there were three fracture dislocations, out of which all three of them had excellent outcomes as per the UCLA score in their latest follow-ups, two of them with 1-year follow-up, and the other with a 6-month follow-up.

Limitations

Our study is limited by small sample size, short duration of follow-ups, and varied indications for RSA. For the same reason, some of our power analyses for comparison of variables were underpowered.

Conclusion

This study demonstrates that primary RSA is a safe and effective procedure for Indian patients suffering from severe glenohumeral arthritis, irreparable rotator cuff tears, and complex fracture dislocations of the proximal humerus. At short-term follow-up, all patients had a significant improvement in functional outcome measures (UCLA and Constant scores) compared to baseline with a low complication rate. These outcomes are independent of age, gender, CSA angle, and RSA angle. The present study should provide a starting point for decision-making in the Indian scenario and needs to be validated by further studies with longer follow-ups and larger patient cohorts.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Supplementary Fixation of Hamstring Tendon Graft in Anterior Cruciate Ligament Reconstruction on Tibial Side with Intraosseous Tunnel: A Prospective Interventional Study

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Abstract

Objective: To find and evaluate the results of a cost-effective technique for supplementary tibial side fixation of hamstring graft without complications which are usually associated with the use of hardware (staples, suture disc, suture post, etc.). **Materials and Methods:** A study was done on 20 young high demand male patients (military soldiers) at our hospital from December 2018 to July 2020 who fulfilled the inclusion criteria. All patients underwent arthroscopic anterior cruciate ligament (ACL) reconstruction ± meniscus repair/balancing and supplementary fixation of hamstring graft on tibial side via intraosseous tunnel by a single surgeon. Subjects were followed up to 1 year for ligament laxity via anterior drawer test/Lachman test, Lysholm knee score and visual analog score (VAS). Average time of surgery and complications if any were noted. **Results:** Out of 20 patients 18 had a mean Lysholm score of 95.6 and VAS was 0 in all patients by the end of 48 weeks. Two patients who underwent ACL reconstruction with meniscus repair (outside-in technique) had a score of <90 at the end of 48 weeks. None of the patients had ligament laxity, tunnel blowout. **Conclusion:** Study concluded that intraosseous tibial side supplementary fixation of hamstring tendon graft when done is a safe, cost-effective procedure and does not have any complications which otherwise are associated with a hardware use.

Keywords: Anterior cruciate ligament reconstruction, hamstring graft, intraosseous tibial tunnel, supplementary fixation

Introduction

Anterior cruciate ligament (ACL) reconstruction is one of the most common procedures performed especially in young high demand individuals.[1] Increased participation of people in supports activities has led to an increased incidence of ACL tears. This has resulted in a quest for refined reconstruction procedures so as to provide a stable knee to the patient. The ultimate goal of such procedure remains to restore the functional level of knee so as to prevent instability and degenerative changes which otherwise ensue in an ACL deficient knee.[2,3] An important aspect of success of such a procedure is the robust and stable fixation of the graft so that early aggressive rehabilitation process can be carried out. Usually, femoral side provides a stable fixation for the graft as compared to tibial side owing to the difference in density of metaphyseal bone of either side.[4] To provide a stable fixation of the graft on tibial side, various methods and implants have been implicated from time to time such as suture disc, screw post, interference screws, and staples with pros and cons of each. Few authors even suggest a dual mode of fixation of the graft on tibial side,[5] however, the same has been associated with symptomatic hardware and hence a need for the removal in a no of patients.[6] Besides, the use of a supplementary device adds to the cost of procedure. In view of all these facts, there is a need to look for a cost-effective, stable tibial fixation method of the graft so as to carry out an early aggressive rehabilitation process without complications such as postoperative ACL laxity and hardware symptoms. We did a study on 20 young healthy male high demand patients (military soldiers) of ACL tear by managing them with arthroscopic ACL reconstruction

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DOI: 10.4103/jajs.jajs_6_22

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Submitted: 02-Feb-2022
Accepted: 21-May-2022 **Published:** 14-Sep-2022

How to cite this article: Dev Jaidev KP, Bhaskarwar A, Singh CM. Supplementary fixation of hamstring tendon graft in anterior cruciate ligament reconstruction on tibial side with intraosseous tunnel: A prospective interventional study. J Arthrosc Jt Surg 2022;9:57-61.

using quadrupled hamstring graft and fixation of the same on tibial side with a bioabsorbable bioscrew along with a supplementary fixation via interosseous tibial tunnel technique and followed for a period of 1 year.

Materials and Methods

A prospective interventional study was carried out in our hospital.

Study design

The study design was a prospective interventional study.

Study duration

The study duration was December 2018–July 2020.

Twenty patients with complete ACL tear with or without meniscus tears were managed by arthroscopic ACL reconstruction and/or meniscus balancing (repair/meniscectomy) and followed up at this center over a period of 12 months after clearance from ethical committee via ethical committee no 15/13/December/BH-2018 date December 13, 2018.

Inclusion criteria

1. Age: 20–40 years
2. Patients with complete ACL tear with or without meniscus tear
3. Patients who gave consent to participate in the study
4. Patients those were willing to follow the postoperative rehabilitation protocol.

Exclusion criteria

- Skeletally immature and elderly patients (<15 years and >50 years),
- ACL deficient knee with degenerative changes
- Multiligamentous injuries.

A detailed preoperative clinical as well as radiological evaluation was done to define the diagnosis. An ACL deficient knee has positive results of Lachman test and or anterior drawer test. All the parameters such as pain, instability, grading of ACL laxity, radio-opaque markers, and magnetic resonance imaging to confirm the diagnosis as well as look for associated injuries were documented. All patients underwent surgical intervention via diagnostic arthroscopy and proceed by a single surgeon, after spinal anesthesia/epidural block, and were followed up with Lysholm knee scale[7] and visual analog score (VAS).[8]

Surgical technique

The patients were positioned supine on the operating table with involved limb in 90° position. Standard arthroscopic portals (anterolateral and anteromedial) were made and diagnostic round was done. ACL tear along with associated injuries to meniscus/cartilage were identified and documented. Footprints of ACL on tibia and femoral side were marked and tibial footprint preserving was preferred wherever possible. A standard graft preparation station was used after harvesting the hamstring graft through a 3 cm oblique incision over pes anserinus and either tripled or quadrupled according to the length harvested. Since the minimum length of semitendinosus required is 28 cm so as to make a quadrupled graft of 7 cm length, gracilis tendon was used if the quadrupled graft dimensions were <7 cm length and an adequate diameter (minimum 8 mm). We used nonabsorbable sutures (Ethibond no 2 or Fiberwire no 2) to prepare the graft in standard fashion. ACL reconstruction was done using a suspensory fixation with Endobutton closed loop on femoral side and bioabsorbable interference screw on tibial side. All patients were considered for supplementary fixation via intraosseous tibia tunnel technique. After bioscrew fixation (2 size up) of the graft, bare area along anterior border of medial collateral ligament (MCL) fibers was identified and an intraosseous tunnel of 2.4 mm diameter was drilled in the posteromedial cortex of tibia with at least 1 cm of cortical bone depth. It is important to note here that approximately 1–1.5 cm of MCL fibers is loosely attached to the tibia in this region which can be identified by gently tapping the MCL fibers using a mosquito forceps. Slightly displacing MCL fibers at this location exposes the underlying bone (which we called bare area) and is the point of drilling the tunnel [Figure 1].

A 16-gauge IV cannula (which we used earlier for the anteromedial portal marking) is reverse threaded with the fiber wire/Ethibond used for preparation of the graft. Alternatively reversed guide wire with loop can also be used for this purpose [Figure 2].

Two of four threads were passed through the intraosseous tunnel into the posteromedial surface of tibia. Both threads were retrieved over the posteromedial cortex back to the starting position of tunnel, i.e., bare area along anterolateral border of MCL. A small mosquito forceps is gently slipped under the loosely attached MCL fibers and threads are retrieved back and the knot is tied under tension [Figure 3].

All patients were subjected to institutional aggressive rehabilitation from postoperative day 1, with closed chain quadriceps hamstring exercises, gait training, and range of motion exercises for a period of 14 days. Patients were discharged from the hospital after suture removal on the 14th postoperative day and were instructed to carry out the physiotherapy in the form of closed chain quadriceps hamstring exercise and ROM exercises. Further follow-up was scheduled at 6 weeks, 12 weeks, 24 weeks, and 48 weeks with documentation of Lysholm knee score and VAS. The immediate postoperative and 48-week follow-up X-rays are depicted in Figure 4.

Results

Study results were subjected to statistical analysis using IBM SPSS software (IBM SPSS Statistics for Windows, Version

Figure 1: Bare area (site for interosseous tunnel)

Figure 2: Reverse threading of 16-gauge IV cannula

Figure 4: Radiographs of two such cases

Table 1: Patients characteristics

Characteristics	Values	SD
Average age (years)	29.8	3.23
Average time of surgery (min)	41.65	5.76
Average period of hospitalization (days)	14	0.87

SD: Standard deviation

27.0.Armonk, NY:IBM Corp) [Tables 1 and 2]. Variables such as mean, median, standard deviation, and *P* value were calculated.

We carried out the study on male subjects with high demand and professional commitment. Right knee was involved in 13 patients and 07 patients had injury in left knee. 07 patients (35%) had associated meniscus injuries and 01 (5%) patient had Grade II Osteochondral lesion (GDII) osteochondral lesion on medial femoral condyle whereas the rest of 12 patients (60%) had ACL tear in isolation [Figure 5].

Anterior drawer test/Lachman test was performed 12 weeks onwards to check for the ACL laxity. 04 patients had GD I ACL laxity on 12 weeks follow-up, however, none of our patients had complaints of either pain or instability of the operated knee joint by the end of 6 months (24 weeks), and the same was confirmed by the absence of ACL laxity with anterior drawer test/Lachman test. Lysholm knee score and

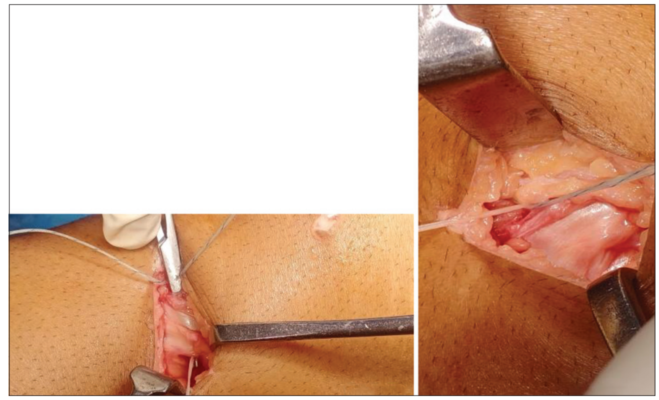

Figure 3: Suture retrieval underneath loose MCL fibers using mosquito hemostat and knot tying. MCL: Medial collateral ligament

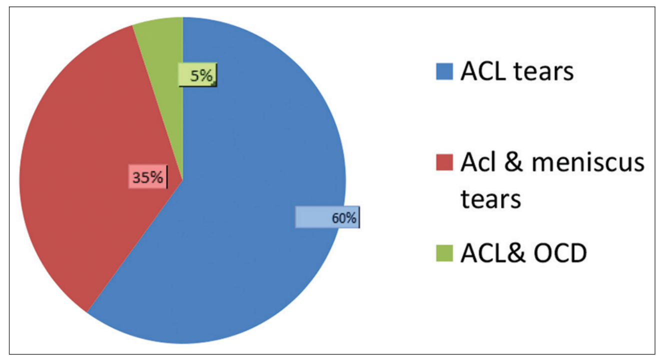

Figure 5: Distribution of injuries. ACL: Anterior cruciate ligament, OCD: Osteochondritis dissecans

VAS showed a progressive increase and decrease respectively by 48 weeks [Figure 6].

All patients except 02, returned to their professional activities by the end of 48 weeks. 02 patients who had undergone meniscus repair complained of pain on running >2.5 km (professional requirement).

Discussion

Arthroscopic ACL reconstruction is one of the most common sports injury surgeries performed presently. Surgical procedure as well as rehabilitation of the same has evolved from time to time with emerging new concepts of surgical technique (e.g., single tunnel, double tunnel, etc.), use of different tendon grafts, and implants for fixing the graft on either side to provide a stable knee at the earliest. Despite different options of the autograft available for reconstruction, hamstring grafts have gained popularity in the last decade due to less donor site morbidity and sufficient graft strength.[6,9,10] Moreover few authors have proposed the use of hamstring grafts because of the decreased incidence of symptoms such as anterior knee pain,[11] numbness around the knee,[12] and pain while squatting at donor site.[13] Various studies done in past have shown that tendon-bone integration, as is the case with hamstring grafts, takes a longer time as compared to the bone-bone integration which happens in bone–patellar

Table 2: Variable statistics

Parameters	Follow-up period	Statistical variables					
		Minimum	Maximum	Range	Mean	SD	*P*
Lysholm knee score	6 weeks	49	80	31	72.4	7.88	<0.001
	12 weeks	77	88	11	86	3.10	<0.001
	24 weeks	80	96	16	91.7	3.59	<0.001
	48 weeks	80	99	19	95.6	5.06	<0.001
Parameters	**Follow-up period**	**Statistical variables**					
		Minimum	**Maximum**	**Range**	**Mean**	**Median**	***P***
VAS	6 weeks	1	12	11	C	4	<0.001
	12 weeks	0	6	6	2	1.5	<0.001
	24 weeks	0	2	2	0.6	0	<0.001
	48 weeks	0	2	2	0.5	0	<0.001

VAS: Visual analog score, SD: Standard deviation

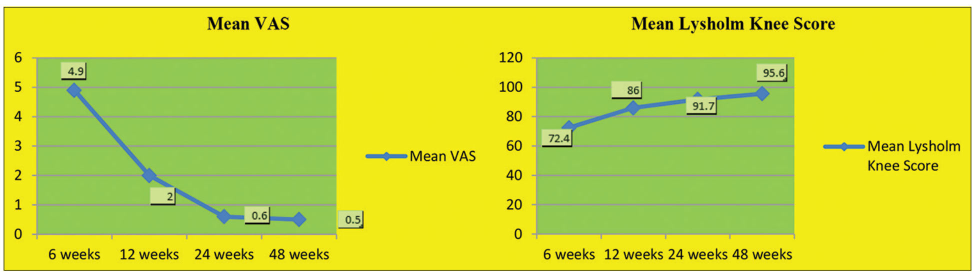

Figure 6: Mean VAS and Lysholm score, VAS: Visual analog score

tendon–bone graft.[14-16] Furthermore the fixation of graft on tibial side has been considered the weakest link during early rehabilitation process resulting in graft elongation and failure in a no of studies.[13,16-18] Studies have also been done to look for and evaluate the supplementary fixation of hamstring graft tendon on tibial side using different implants with conflicting evidence,[12,19] Though the indications of performing such a fixation are controversial, whenever done they definitely lead to an added cost of procedure as well. As is a known fact that evolution of modern medicine and hence the treatment comes at some cost and this factor plays an important role in making the treatment available to masses. The purpose of our study was to look for and evaluate a cost-effective supplementary method of tibial fixation and at the same time avoid complications which otherwise are associated with implants such as suture disc, suture post, and staples. We evaluated our technique by postoperative follow-up using Lysholm knee score as this score focuses on the knee instability assessment, as perceived by the patient, and has been considered gold standard in the evaluation of patients with ACL injuries.[7,20] In our study, all but two patients (who had undergone meniscus repair) were asymptomatic at the end of 1-year follow-up. However, none of the patients had ACL laxity as evaluated by Lachman test/Anterior Drawer test. None of the patients had a tunnel blowout. As for as the indication of performing the supplementary fixation is concerned, we carried out this procedure in all those patients who underwent arthroscopic ACL reconstruction despite the dimensions of quadrupled hamstring graft available to us. There are a considerable number of studies emphasizing on the type of material used (for fixation on femoral as well as tibial side, i.e., bioabsorbable or metal screws) rather than the available graft length in femoral or tibial tunnel.[21,22] These studies showed conflicting results in postoperative graft laxity with different lengths of the graft tendon available in the respective bone tunnels[23,24] thereby suggesting that graft length cannot be the sole criteria responsible for postoperative ACL graft elongation. Overall intraosseous tibial tunnel fixation appears to be a viable method of supplementary ACL graft fixation on tibial side. There are no complications which otherwise are associated with metal screws, suture posts, suture discs, staples, etc., Moreover, it does not add to the cost of surgery also.

Though our study was a prospective study we had few shortcomings as well: a small sample size, no comparison group, and use of KT-1000 (unavailability of instrument). Another shortcoming is absence of female gender group in the study which also has a high incidence of such injuries due to increased athletic participation in the last few decades.

Conclusion

A supplementary tibial side hamstring graft tendon fixation via intraosseous tunnel technique is a safe procedure and provides a stable fixation. At the same time, it has advantages such as absence of hardware symptoms (hence avoiding the need for a second surgery if required), no additional cost of procedure, and absence of postoperative graft tendon laxity, thereby making the knee available to carry out an aggressive rehabilitation in immediate postoperative period of ACL reconstruction.

Financial support and sponsorship

The study did not encounter any financial implications as it did not involve the use of additional implants other than those used for routine ACL reconstruction. The routine implants used are those which were purchased as part of Army Hospitals Priced Vocabulary Store system (Government procurement policy)

Conflicts of interest

There are no conflicts of interest.

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Does Subscapularis Insufficiency in Patients with Subacromial Impingement Syndrome Correlate with Proximal Migration of Humerus? A Cross-Sectional Observational Study

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Abstract

Purpose: To evaluate the correlation between subscapularis insufficiency and functional subacromial impingement syndrome (SAIS). **Patients and Methods:** Twenty patients with nonstructural subacromial impingement with at least one positive clinical test including Neer's, Hawkins Kennedy, and Codman drop arm test, were recruited for this observational study. Subscapularis weakness was evaluated clinically via Gerber lift-off test, Bear Hug test and by Belly Press test, and by dynamometer, and its insufficiency was confirmed by evaluating changes in muscle atrophy and fatty infiltration on magnetic resonance imaging (MRI). Subscapularis weakness was then matched with radiological parameters of proximal migration of shoulder, namely upward migration index (UMI) and Acromiohumeral interval (AHI) on X-ray and MRI, respectively. **Results:** A significant association ($P < 0.05$) was seen between subscapularis insufficiency and radiological parameters of SAIS, namely UMI and AHI. **Conclusion:** There exists a significant positive correlation between subscapularis insufficiency and proximal migration of humerus. Patients with clinical and radiological signs of subacromial impingement and without any evidence of structural abnormality should be investigated for an underlying subscapularis insufficiency.

Keywords: Humeral excursion, humeral migration, subacromial impingement syndrome, subscapularis, supraspinatus

Introduction

Subacromial impingement syndrome (SAIS) accounts for 44%–65% of shoulder complaints during physician visits.[1] Neer first classified shoulder impingement into two categories structural and functional.[2] The structural impingement is caused by compression of supra-humeral structures in the subacromial space due to a bony growth or soft-tissue inflammation. However, functional impingement results from narrowing of the subacromial space because of proximal migration of humerus following altered scapulohumeral mechanics, resulting from glenohumeral instability or imbalance of muscles around the shoulder joint.[3-5] This functional impingement results from the loss of balance between the coronal (deltoid and supraspinatus) and transverse (subscapularis and infraspinatus) force couples of the shoulder joint.[5]

Previous studies have established that subscapularis, along with latissimus dorsi, teres major, and infraspinatus, resists the upwardly directed shearing forces of the deltoid in the coronal plane.[5-8] It also exerts compressive forces across the shoulder joint to keep the humeral head centered in the glenoid cavity.[5-8] As long as this transverse force couple remains intact, the glenohumeral joint remains centered, and proximal migration of the humeral head is prevented.

The subscapularis is the largest and strongest of the rotator cuff muscle, exerting 53% of the total cuff strength.[9] Architectural studies have also established that inferior fibers

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DOI: 10.4103/jajs.jajs_76_22

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Submitted: 25-Jun-2022 **Revised:** 02-Aug-2022
Accepted: 12-Aug-2022 **Published:** 14-Sep-2022

How to cite this article: Dhanjani B, Jain G, Tank S, Krishna A, Kumar M, Kumar V. Does subscapularis insufficiency in patients with subacromial impingement syndrome correlate with proximal migration of humerus? A cross-sectional observational study. J Arthrosc Jt Surg 2022;9:62-6.

of subscapularis muscle provide a passive buttressing effect, resisting anterior dislocation.[5] The role of the subscapularis muscle in the pathogenesis of SAIS has not been adequately investigated, despite the primacy it has in the rotator cuff muscles and the fact that there are a few reports in the literature associating subscapularis weakness to proximal migration of the humeral head.[10-13]

There exists a need to study the cause and effect relationship between shoulder impingement and subscapularis insufficiency. This judgment will assist clinicians to evolve methods, clinical or otherwise, to identify a failing subscapularis at its earliest and prevent functional SAIS from developing. The present study was undertaken in the background brought out above to test whether there exists a positive correlation between subscapularis insufficiency and SAIS.

Patients and Methods

The current work was an observational study conducted at a tertiary level teaching institute after approval from the institute ethics committee. A written, informed consent was obtained from all the patients enrolled in the study.

Patients with chief complaints of shoulder pain of at least 1 month in whom either the Hawkins–Kennedy test or Neer's test for subacromial impingement was positive were recruited in this study. Structural causes of subacromial impingement, namely a hooked acromion (Bigliani type III acromion), acromioclavicular osteophytes, bony spurs of the acromion, calcification of the coracoacromial ligament, os acromiale, subacromial bursitis, and calcific tendinitis, evident either on X-rays or magnetic resonance imaging (MRI), were excluded from the study. Patients with shoulder instability as evaluated clinically by Jobe's relocation test and apprehension test, with signs and symptoms of any systemic inflammatory disease, infection or arthropathies, with periarthritis of the shoulder joint, with the affection of bilateral shoulder joint, with fractures or dislocations of the shoulder joint, or any neuromuscular disorders involving the upper limb, were also excluded from the study.

A total of 20 consecutive patients who qualified for the inclusion and exclusion criterion as mentioned above were then selected and evaluated clinically in detail for subacromial impingement and integrity of rotator cuff muscles. Consequently, we performed three clinical tests for subscapularis muscle weakness, namely Bear hug, Gerber lift-off, and belly press test. The former was also tested by a dynamometer. To test the integrity of other rotator cuff muscles, Jobe's test, Infraspinatous test, and Horn blower's test for supraspinatus, infraspinatus, and teres minor was performed, respectively.

Upward migration index (UMI) was measured on a true anteroposterior radiograph of the shoulder in neutral rotation [Figures 1 and 2]. The acromiohumeral interval (AHI)

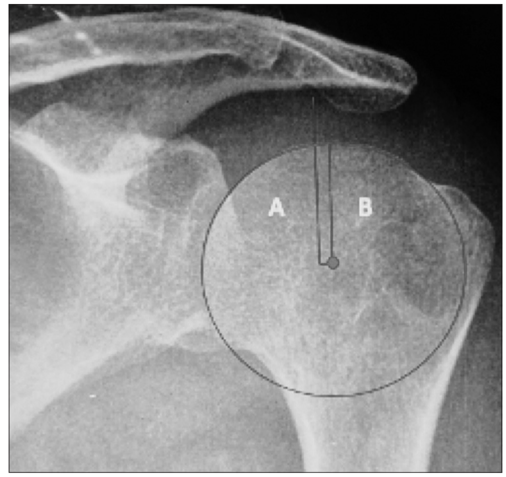

Figure 1: On Plain radiograph AP view, UMI was measured by dividing the distance between Centre of humeral head to the under surface of the acromion (A) with the radius of humeral head (B). UMI: Upward migration index

was evaluated on MRI [Figure 3]. Atrophy and fatty infiltration in subscapularis muscle on MRI served as an indicator of the degree of subscapularis insufficiency. Next, subscapularis insufficiency, as detected clinically, dynamo metrically and on MRI, was matched against the radiological parameters (UMI and AHI) of proximal migration of humerus to evaluate the correlation between these two entities. All the clinical tests and the measurements of the radiological parameters were done independently by two authors. Any discrepancies were resolved by the senior co-author.

Statistical analysis

All the data were evaluated using SPSS version 17 (SPSS. Inc, IBM, CHicago, illinois, USA). Categorical variables were analyzed using the Chi-square test or Fischer's exact test. An Independent *t*-test or rank-sum test was applied to compare quantitative variables expressed as mean ± standard deviation. A *P* Value <0.05 was considered statistically significant.

Results

Patients included in the present study had a mean age of 45.2 years and consisting six males (30%) and 14 females (70%). Out of the 20 patients, the right side was affected in 12 patients (60%), and the left side in eight patients (40%). Both Hawkins–Kennedy tests and Neer's test were positive in 15 patients. Out of these 15 patients, four patients also tested positive for the Codman's drop arm test. Out of the remaining five patients, three patients had an isolated Hawkins–Kennedy test positive, and the other two had an isolated Neer's test positive. Fourteen patients out of 20 had subscapularis weakness as determined clinically by the Belly press test, Gerber lift-off test, and Bear hug test (at 45° and 90°). Patients with a positive lift-off test and bear hug test at 90° had a significantly lower AHI [Table 1]. However, none of the clinical tests for subscapularis insufficiency had any significant association with UMI [Table 2].

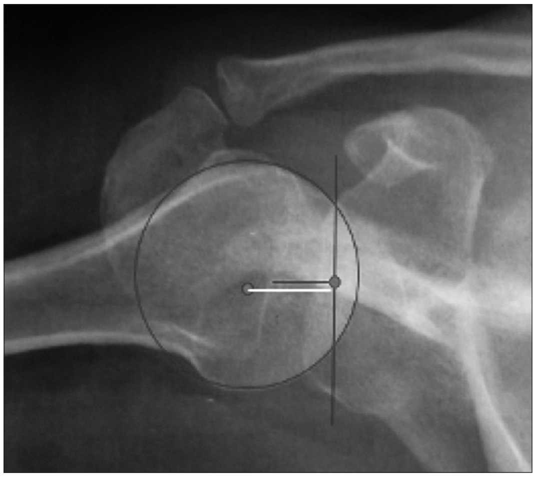

Figure 2: Axial view of shoulder showing how to see anterior translation of humeral head. Glenoid line was drawn connecting superior and inferior edges of glenoid rim; and equator of glenoid marked by bisecting this line. A line drawn from centre of humeral head perpendicular to the first line. If centre of humeral head lies above the glenoid equator, anterior translation has occurred

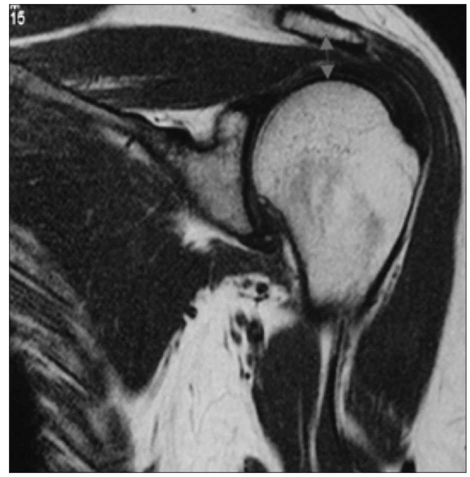

Figure 3: T1-weighted oblique coronal image of MRI shows normal AHI. AHI was calculated by measuring the minimum distance between inferior aspect of acromion and humeral head. MRI: Magnetic resonance imaging, AHI: Acromiohumeral interval

Seven patients with either mild or moderate subscapularis muscle atrophy, as determined by MRI, showed a significantly lower AHI as compared to patients with no atrophy ($P = 0.03$) [Table 3]. However, on analysis of these seven patients with mild-to-moderate atrophy of subscapularis with UMI, a nonsignificant association was revealed ($P = 0.06$). This finding stands in contrast to the findings of a correlation between muscle strength as revealed by a dynamometer and radiological parameters of SAIS. Subscapularis muscle strength, as estimated by dynamometer, had a significant positive correlation with UMI ($r = 0.5$, $P = 0.02$), but not with AHI ($r = 0.1$, $P = 0.63$) [Figure 3].

Table 1: Relation of acromiohumeral interval with results of clinical tests for subscapularis weakness

Clinical test	AHI, mean±SD		P
	Positive test	Negative test	
Bear hug 90	7.40±1.26	8.80±0.79	0.008
Bear hug 45	7.77±1.3	8.7±0.95	0.11
Lift-off	7.38±1.41	8.58±0.90	0.03
Belly press	7.92±1.44	8.38±0.92	0.44

SD: Standard deviation, AHI: Acromiohumeral interval

Table 2: Relation of upward migration index with results of clinical tests for subscapularis weakness

Clinical test	UMI, mean±SD		P
	Positive test	Negative test	
Bear hug 90	1.26±0.10	1.31±0.09	0.21
Bear hug 45	1.26±0.09	1.33±0.10	0.16
Lift-off	1.24±0.11	1.31±0.08	0.10
Belly press	1.26±0.10	1.32±0.10	0.16

SD: Standard deviation, UMI: Upward migration index

Table 3: Relation between upward migration index and acromiohumeral interval and the degree of muscle atrophy

Degree of muscle atrophy	Affected side, mean±SD	
	AHI	UMI
None (13)	8.54±0.97	1.31±0.08
Mild (5) or moderate (2)	7.29±1.38	1.23±0.12
P	0.03	0.06

SD: Standard deviation, UMI: Upward migration index, AHI: Acromiohumeral interval

Discussion

Many authors have studied the role of subscapularis as a contributor in stabilizing the humeral head and preventing its upward migration. Cadaveric studies have shown that the inferior pull of the subscapularis muscle is necessary to negate the superior force vector generated by supraspinatus and deltoid muscle.[8,14,15] This inferior pull prevents the upward migration of the humerus and stops a functional subacromial impingement from developing. Bezer *et al*. and Saupe *et al*. have also corroborated the same by their cross-sectional studies,[12,16] wherein the degree of fatty degeneration and the grade of tear of the subscapularis muscle correlated with a reduced acromiohumeral distance. In another study, Farfaras *et al*. found the subscapularis tendon to have increased inflammatory markers and histological and ultrastructural features of degeneration in patients with SAIS.[17]

Previous studies have evaluated the correlation between subscapularis tear and subacromial impingement by either radiological findings of fatty degeneration and muscle atrophy or by arthroscopic evidence of partial or complete tear of the subscapularis.[8,12,15-17] There remains a need to clinically evaluate subscapularis weakness and explore whether a clinically detected subscapularis weakness is sufficient to cause a proximal migration of humerus and a functional subacromial impingement from developing. As this clinico-radiological correlation has not been studied in literature hitherto, authors in this study have tried to overcome this lacuna by correlating both the clinical and radiological parameters of subscapularis insufficiency with parameters of proximal humeral migration.

In this study, out of a total of 20 patients with functional subacromial impingement, 14 patients had subscapularis weakness when assessed dynamometrically and clinically with Gerber lift-off, belly press, and bear-hug test (at 90° and 45°). The bear hug test had a sensitivity of 75% and a specificity of 92%. In a study by Schiefer *et al*.,[18] Belly press had a sensitivity of 45% and a specificity of 92% and Gerber lift-off test had a sensitivity of 25% and a specificity of 92% to clinically detect cases of subscapularis weakness.

However, only seven patients had mild-to-moderate atrophy and fatty infiltration of the subscapularis when evaluated radiologically on MRI.

In one study by Nové-Josserand *et al*. conducted on 206 patients, rotator cuff tendon tears, fatty degeneration, and muscular atrophy in subscapularis were correlated with a reduced AHI and coracohumeral interval.[11] Authors in this study also concluded that only those tears of subscapularis that were associated with tears of supraspinatus tendon resulted in proximal migration of humerus and a low AHI. However, Zhu *et al*., in their study, concluded that subscapularis tears alone were sufficient to cause a proximal migration of humerus and a low AHI and coracohumeral interval.[19] In another study, Siow *et al*. showed that a high-grade tear of subscapularis was associated with reduced AHI. However, the effect of low-grade tears or weakness of the subscapularis muscle without any tears on AHI was not reported.[20]

Contrary to the findings of the majority of studies as reported above, Cetinkaya *et al*. in his study concluded that subacromial impingement was not related to subscapularis tendon tear and that superior humeral migration as indicated by the acromiohumeral distance was caused by supraspinatus tear alone.[21] However, the findings of the study by Cetinkaya *et al*. stands in contrast with other studies reported in the literature, and the conclusions thereof have been refuted conclusively by subsequent authors.

In all the studies cited above proximal migration of humerus in patients with subacromial impingement has been correlated with subscapularis tears detected arthroscopically or radiologically on MRI. None of the studies in the literature has till date laid any emphasis on the clinically detected subscapularis weakness and its correlation with proximal migration of humerus in patients with subacromial impingement.

The present study has tried to fill this lacunae in the literature by correlating a clinically detected subscapularis weakness with proximal migration of humerus and other radiological parameters of functional subacromial impingement. The results of the present study thus provide, in whatsoever small measure, a new insight into the understanding of the etiopathogenesis of SAIS and subscapularis insufficiency and add a new dimension to the ever-evolving management protocols for these conditions.

A note should be made of a few limitations of the present study. One major limitation of the current study is the limited accuracy of the clinical tests in terms of their specificity and sensitivity to detect SAIS and subscapularis insufficiency.[22] However, since the study was undertaken to test the clinical applicability of the standard test of subscapularis insufficiency and its correlation with SAIS, the criterion for diagnosing SAIS and subscapularis weakness was restricted to their respective clinical tests only. Furthermore, owing to the observational cross-sectional nature of the study design, the causal relationship between subscapularis insufficiency and functional SAIS cannot be established, for which authors recommend further analytical prospective studies to conclusively cement the findings of the present study.

Conclusion

We can conclude from the current study that patients with positive clinical signs of subacromial impingement and without any evidence of structural abnormality can have an underlying rotator cuff insufficiency. Besides obviating the need for surgery, the observation not only lends credence to the fact that clinical examination of subscapularis weakness takes precedence over the radiological confirmation of its insufficiency but also enables the physician to catch hold of a developing functional subacromial impingement at its initial stages by identifying a failing subscapularis at its nascent stages. Subscapularis strengthening exercises in such patients should alleviate the symptoms of subacromial impingement and improve functional outcomes.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Functional Outcomes after Modified Blair's Procedure for Ankle Arthritis Secondary to Hawkins Type III Talus Injuries: A Retrospective Cohort Study

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Abstract

Introduction: The management of ankle arthritis secondary to traumatic talar injuries remains challenging, given the complexity of the majority of cases and the presentation of patients with avascular necrosis of the talus. While several treatment options have come up, the arthrodesis of the tibiotalar joint, as first described by Blair in 1943, remains a useful modality, especially in resource-limited settings. However, few studies have reported the functional outcome after the modified Blair's procedure. This study sought to describe the functional outcomes after the modified Blair's procedure for ankle arthritis secondary to Hawkins type III talus injuries. **Methods:** This retrospective cohort study was performed in a tertiary care center in northern India, which enrolled all patients with posttraumatic ankle arthritis due to Hawkins type III talus injuries who had received modified Blair's ankle arthrodesis from January 2018 to January 2021. The primary outcomes were scores on the Visual Analog Scale (VAS) for pain and American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale, which had been recorded both before treatment and 1-year postoperatively, and were compared through a paired *t*-test. **Results:** A total of 11 patients were included. Bony fusion occurred in a mean ± standard deviation duration of 21.73 ± 1.90 weeks. AOFAS score improved preoperatively from 41.45 ± 6.56 to 80.09 ± 5.09 at 1-year postoperatively (mean difference: 38.64, 95% confidence interval [CI]: 34.24–43.03, $P < 0.001$). VAS score for pain improved from 6.27 ± 1.10 preoperatively to 0.73 ± 0.78 1-year postoperatively (mean difference: 5.54, 95% CI: 4.85–6.24, $P < 0.001$). **Conclusions:** Modified Blair's procedure has the potential to provide patients of posttraumatic ankle arthritis with significant pain relief and excellent functional outcomes. The remaining subtalar and talonavicular motion allows patients to have satisfactory walking ability without considerable difficulty.

Keywords: American Orthopaedic Foot and Ankle Society, ankle osteoarthritis, Hawkins classification, talus, tibiotalar fusion, Visual Analog Scale

Introduction

Talus fractures are among the common injuries around the ankle joint which usually result from high energy trauma and can lead to significant functional impairment.

The majority of talus fractures occur around the neck of the talus (50%–80%), whereas fracture of the talar body accounts for 13%–23%, with only 5%–10% occurring at the head.[1] Owning to its complex anatomy, multiple articulation sites, and tenuous blood supply, we still continue to have a high complication rate in its management.[2]

Hawkins in 1970 introduced the world to a useful classification of talar neck fractures, which is still widely followed. Hawkins Group I includes all patients with undisplaced vertical neck fractures of the talus. Group II includes individuals with subtalar joint subluxations/dislocations with displaced fractures and normal ankle joints. In Group III, patients have a displacement of fracture with dislocation of both ankle and subtalar joint.[3] The incidence of avascular necrosis (AVN) of the talus is different in each type with 75%–100% in the case of Group III fracture–dislocation.[3,4]

Access this article online	
Quick Response Code:	**Website:** https://journals.lww.com/jajs
	DOI: 10.4103/jajs.jajs_66_22

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Submitted: 04-Apr-2022 **Revised:** 29-Jul-2022
Accepted: 13-Aug-2022 **Published:** 14-Sep-2022

How to cite this article: Singh S, Rastogi D, Waliullah S, Singh SK, Ozair A. Functional outcomes after modified Blair's procedure for ankle arthritis secondary to Hawkins type III talus injuries: A retrospective cohort study. J Arthrosc Jt Surg 2022;9:67-71.

Hawkins recognized the importance of the blood supply to the talus and depicted three types of fracture patterns, among which type III had the maximum incidence of AVN of 91%.[5] AVN of the talus is a dreaded sequel whose chances increase with the severity of trauma and damage to its precarious blood supply. Its diagnosis can be challenging for treating surgeons and one should be suspicious of it, especially in high-energy trauma.[6,7] Posttraumatic arthritis is another frequent complication of Hawkins type III injury with prevalence ranging from 16% to 100%.[8-10]

Minor deviation from its normal anatomy during osteosynthesis may result in significant deterioration in function, commonly leading to debilitating and painful posttraumatic arthritis at the ankle, subtalar and neighboring joints, and other complications such as AVN of the talus and ankle stiffness. These injuries, thus, have the potential to significantly affect the lifestyle of the patients and their prompt management is of utmost importance.

Various treatment modalities have been described in the literature, but long-term complications such as ankle arthritis and AVN are still commonly seen.[1]

Arthrodesis of the ankle joint provides good pain relief at the expense of the range of motion in patients with end-stage arthritis. In 1943, Blair demonstrated the excision of the talus body by sliding out of a cortical bone graft from the anterior surface of the tibia onto the head of the talus.[11]

Thereafter, Morris *et al*. altered the procedure by removing the body of the talus and placing a Steinmann pin through the calcaneum to the tibia for stabilization and thereafter screwing the tibial sliding graft.[12] Subsequently, Dennis and Tullos used a similar procedure but did not use the Steinmann pin for ankle stability.[13]

Most of the authors have advised for removal of the talar body, even though it sustains nearly four times the loads of body weight during normal walking. Substantial changes are expected around the remaining anterior and medial facet of the talus, increasing the likelihood of degenerative arthritis around them.

This study aims to describe the functional outcome of modified Blair's procedure for ankle arthritis secondary to Hawkins type III talus injuries.

Methods

Study design

The present work was a single-arm, retrospective cohort study conducted and reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[14] The study was performed at the department of orthopedic surgery in a tertiary-care, government-funded institution located in northern India, following the ethical guidelines of the Declaration of Helsinki. Informed consent had been previously collected from the patients or their attendants at the time of presentation for future research activities. Patient data were collected through chart review and digitized, with confidentiality being strictly maintained, through the use of an assigned identification number.

Study participants

All adult patients who presented in our outpatient department from January 2018 till January 2021 (>18 years) with neglected Hawkins type III talus injuries and patients with compound fracture talus (Gustilo–Anderson type I and II) who eventually developed complications such as ankle arthritis and AVN of the talus were included. Patients with other fractures, crush injuries foot (Gustilo–Anderson type III), and vascular injuries were excluded. We confirmed the diagnosis of ankle arthritis and AVN of talus with the help of X-rays and MRI.

Study outcomes

The primary outcomes were pain, as assessed by the Visual Analog Scale (VAS), and surgical outcome/Functional outcomes, as assessed by the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score, both of which are well-validated instruments in foot and ankle surgery.

Care pathway and surgical technique

All these patients were managed by modified Blair's procedure for ankle arthritis and AVN talus.[12] A single senior surgeon performed all the procedures. The patients were laid in a supine position under spinal anesthesia and with the surgical site painted and adequately draped. Two tendons, the extensor hallucis longus, and extensor digitorum longus were then palpated and a skin incision of about 5 cm proximal to the ankle joint line with 2 cm distal to it was made. After superficial dissection, the neurovascular bundle was visualized and retracted medially. The capsule, periosteum, and synovium were then incised. After adequate joint exposure, the tibial articular surface was exposed and curetted with a necrotic part of the talar body excised. The remaining part of the talar body was left intact while ensuring maximum preservation of tibiotalar surfaces. Now the best possible anatomic reduction was achieved, and a sliding graft of size 2 cm × 5 cm was retrieved from the distal anterior portion of the tibia and snuggly fitted into a slot into the neck of the talus. The foot was kept in neutral flexion, slight valgus (0° to 15°), and 10° to 15°-external rotation, while the graft was slid into place. The graft placement and alignment of the foot were then carefully analyzed under C-arm guidance and the tibiotalar joint was fused with the placement of two cancellous screws.

Postoperatively, a below-knee plaster of Paris cast was applied for 12 weeks.

The decision of partial or full weight bearing on the treated limb was made after radiographic evidence of healing of the graft and Tibiotalar bony fusion.

Data collection and follow-up

Data for this study were collected via a retrospective chart review. The VAS pain score and the AOFAS scores were recorded postoperative 1-year follow-up and compared with preoperative values. Follow-up had been conducted both in-person and telephonically.

Statistical analysis

Statistical analysis was carried out in Stata Base Edition V17.0 (StataCorp LLC, College Station, TX, USA). Shapiro–Wilk test was utilized to ascertain the normality of the two major clinical outcomes, which was nonsignificant, indicating parametric data. Therefore, these outcomes were compared using paired *t*-test. No missing data were present.

Results

A total of eleven patients were enrolled in our study with their demographic details mentioned in Table 1. Ten patients had reported to our hospital more than 1 year after their primary injury having been managed elsewhere, while one patient had come to us immediately after the injury. Tibiotalar bony union was achieved in the included patients at the mean of 21.73 ± 1.90 weeks after the modified Blair's procedure.

Functional outcomes of the ankle using the AOFAS Ankle-Hindfoot Score as well as the VAS score for pain are summarized in Figure 1 and compared in Table 2.

AOFAS score improved preoperatively from 41.45 ± 6.56 to 80.09 ± 5.09 at 1-year postoperatively (mean difference: 38.64, 95% confidence interval [CI]: 34.24–43.03, $P < 0.001$). VAS Score for pain improved from 6.27 ± 1.10 preoperatively to 0.73 ± 0.78 1-year postoperatively (mean difference: 5.54, 95% CI: 4.85–6.24, $P < 0.001$). The total postoperative period was uneventful for all patients.

One of the patients had suffered a compound injury and had then reported directly to our institution. She was primarily managed by external fixator application over the leg and foot with the second procedure (ankle arthrodesis) performed after 16 weeks [Figure 2].

The management of another exemplary case, which was a 28-year-old male, has been described in Figure 3.

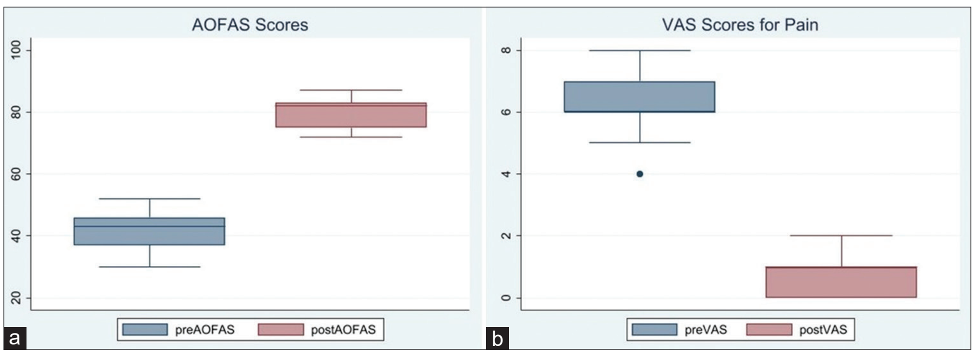

Figure 1: Box-and-Whisker plots of scores of included patients on (a) AOFAS Ankle-Hindfoot Scale, and (b) VAS for Pain. Pre, Preoperative; Post, postoperative. VAS: Visual Analog Scale, AOFAS: American Orthopaedic Foot and Ankle Society

Figure 2: Case of 49-year-old female who presented with compound fracture–dislocation of talus. (a) Preoperative radiograph showing Hawkins type III talus injury. (b) Debridement of wound performed followed by application of external fixator, with ankle arthrodesis performed after 16 weeks as a second procedure. (c) AP and lateral radiographic views from the immediate postoperative period. (d) AP and lateral radiographs at 1-year postoperative period. (e-g) Restoration of ankle function at 1-year postarthrodesis, with shape of the foot maintained, and the patient seen standing on both foot in (e and f). AP: Anteroposterior

Discussion

Relevance to clinical practice

Our study found that the modified Blair's procedure helped improve functional outcomes as measured by the AOFAS Ankle-Hindfoot Score and pain score in a small sample of patients suffering from ankle arthritis secondary to traumatic Hawkins type III talus injuries.

Ankle arthritis is a physically disabling condition whose treatment is quite challenging for surgeons yet functionally rewarding for patients. Till date, the management of ankle arthritis is still dubious as both have complications such as aseptic loosening and wound complications fracture, whereas both are considered promising techniques for end-stage arthritis of the tibiotalar joint.[15] In unsalvageable fracture talus or such cases with a bad prognosis, ankle arthrodesis becomes a primary treatment method.

The biomechanical properties of the ankle joint make it suitable for arthrodesis.

Since it is a hinge joint and although its axis continuously changes with rotation, fixation in a neutral position does not alter its functionality as much.[15] Talus is well surrounded by malleoli and congruent tibial plafond provides a potential bone surface for fusion.

The most performed surgical procedure for the treatment of neglected Hawkins type III fracture or compound fracture–dislocation with displaced fracture talus is the modified Blair's fusion. In 1943, Blair originally described two cases with tibiotalar fusion without internal fixation as the primary treatment for fracture of the talus. Both healed with a good subjective outcome.[11]

Table 1: Baseline characteristics of included patients in the current study (n=11)

Variable	Value
Age, median (IQR)	39 (35-43)
Sex (male/female)	7/4
Time elapsed for tibiotalar fusion (weeks), mean±SD	21.73±1.90
Occupation, frequency (%)	
Labourer	3 (27.3)
Farmer	3 (27.3)
Housewife	2 (18.2)
Service personnel	2 (18.2)
Shopkeeper	1 (9.1)

SD: Standard deviation, IQR: Interquartile range

In our study, eleven cases were included. Ten of these were neglected cases of Hawkins type III injuries (i.e., fracture–dislocation neck of the talus with a full displacement of the subtalar and ankle joint), whereas one was compound fracture–dislocation talus. All these cases were then eventually managed by modified Blair's arthrodesis.

Morris *et al*., in 1971, had deduced the primary removal of the comminuted bony parts of talus fractures of the talar body as well as those with closed Group-III injuries since these fractures have high chances of AVN.[12] In the current study, a modification of this technique using rigid internal fixation with compression lag screws was executed. The excision of only the avascularized portion of the talar body was done, while attempts were made to preserve as much tibiotalar articular surface as possible so that proper load transmission could occur from leg to foot. Hence, it improves mechanical stability and reduces the chance of implant failure and further degenerative arthritis. Such a form of treatment allows the maintenance of hindfoot height, preservation of some subtalar joint motion, and cosmetically better foot appearance.[13,16-20] Another surgical option was talocalcaneal arthrodesis with talectomy for treatment of advanced talar osteonecrosis with

Figure 3: A 28-year-old male was a neglected case of ankle fracture–dislocation, (a and b) with preoperative radiographs showing Hawkins Type III talus injury. (c and d) Radiographs taken in the immediate postoperative period, and (e and f) radiographs at 1-year postoperatively

Table 2: Preoperative and postoperative scores of included patients on the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale and the Visual Analogue Scale (VAS) for Pain.

Variable	Value (Mean±SD)	Mean Difference	95% CI	Paired *t*-test	*P*
Preoperative AOFAS score	41.45±6.56	38.64	34.24 to 43.03	19.57	P<0.001
Postoperative AOFAS score	80.09±5.09				
Preoperative VAS score	6.27±1.10	5.54	4.85 to 6.24	17.76	P<0.001
Preoperative VAS score	0.73±0.78				

less collapse of hindfoot height. However, patients were found to have poor functional outcomes and hence the talectomy approach is no longer commonly used for this indication.[18]

In our study, the AOFAS score improved from 41.45 ± 6.56 to 80.09 ± 5.09 at 1-year postoperatively (mean difference: 38.64), while VAS Score for pain improved from 6.27 ± 1.10 to 0.73 ± 0.78 1-year postoperatively. All patients had satisfactory returns to their daily activities with no major complaint of pain in subsequent 1-year follow-up. These patients also reported a significant increase in ankle hindfoot score from a mean score of 41.45 (mean preoperative score) to the mean of 80.09 (mean postoperative score). Similarly, Van Bergeyk *et al*. reported a mean ankle hindfoot score of 67 out of 100 among seven patients.[17]

Meanwhile, Wang *et al*. in 2014 included 28 patients and evaluated VAS score and ankle hindfoot score at 1-year follow-up.[21] They reported a postoperative ankle hindfoot score of 83.13 ± 3.76 improving from 45.38 ± 3.21, while VAS decreased from 8.01 ± 0.63 to 2.31 ± 1.05. Furthermore, Tenenbaum *et al*., in 2014, evaluated a postoperative VAS score of 1.7 ± 2.2 and ankle hindfoot score of 72.1 ± 10.1 at 2-year follow-up.[22] This difference in scores is based on tibiopedal movement and ability of patients to do activities without any symptoms, The overall physical functioning of patients with modified Blair's procedure was significantly lower than the general population. This physical dysfunction in these patients was predictable after such a major hindfoot injury. Despite this, all patients were able to return to their preinjury daily routine activities and were quite satisfied with the management and the pain relief. Since most of our patients were laborers with an intense level of physical activities, ankle arthrodesis proves to be a viable and cost-effective option with promising results.

Limitations

Our study had several limitations. First, we had a small sample size, which prevented us from identifying predictors of better outcomes through multivariate regression analyses. Second, our follow-up was limited to 1-year, which in itself was challenging given that patients in resource-limited settings like publicly funded hospitals frequently abandon both in-person and telephonic follow-up. Third, we did not utilize a patient-reported quality of life scale such as the 36-Item Short Form Survey (SF-36). Finally, we did not have much data available on other predictors of ankle arthritis after traumatic talus injuries, due to the lack of records possessed by patients.

Conclusions

Modified Blair's procedure has the potential to provide patients with posttraumatic ankle arthritis with significant pain relief and excellent functional outcomes as the advantage of producing less shortening and allowing motion to remain at the talonavicular and anterior subtalar joints as evident by excellent postoperative ankle hindfoot score. Given the low expenses involved compared to other alternatives, it may be a significantly cost-effective measure, especially among the low-income population. The remaining subtalar and talonavicular motion allows patients to have satisfactory walking ability without considerable difficulty.

Acknowledgement

We wish to acknowledge the contributions of Prof Santosh Kumar to this work, who expired prior during its conduct.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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Surgical Tips/Tricks on Minimally Invasive Anterior Hip Replacement

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Abstract

Minimally Invasive Anterior Hip Replacement is an increasingly popular surgical technique of doing total hip arthroplasty (THA) offering several benefits and has been shown in various literature. However, the technique being challenging and specific, if not followed can lead to several complications. This article outlines the author's technique of performing the Minimal Invasive Anterior Hip Replacement using a mobile leg positioner designed by Medacta (Strada Regina, Switzerland) on a standard operating table, highlighting tips/tricks for performing it safely.

Keywords: Total hip arthroplasty (THA), tips/tricks, Direct anterior approach (DAA)

Introduction

The direct anterior approach to the hip joint was first described by Carl Heuter in 1881[1] and later popularized by Smith-Peterson. Despite the long history, over time, few centers have dedicated themselves to the furtherance of this approach, most notably the Judet Brothers. Over the past 15 years, the direct anterior hip approach has gained increasing popularity in total hip arthroplasty, which has been made possible due to advances in training, component design, and surgical equipment Total hip arthroplasty (THA).

The anterior approach is a pure muscle-sparing, internervous, intermuscular technique compared to its counterpart approaches (lateral and posterior). Magnetic resonance imaging (MRI) studies have demonstrated significantly lower soft tissue damage in the anterior approach as opposed to the lateral approach, with less fatty atrophy of the gluteus musculature on MRI at 6 months[2] and lower rates of heterotrophic ossification.[3]

However, the approach can be technically challenging with a steep learning curve, with early difficulties in achieving correct component positioning, and with intraoperative fracture. This fortunately can be overcome with adequate training and the aid of fluoroscopy.[4]

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DOI: 10.4103/jajs.jajs_7_22

Patient selection is important at the beginning. The ideal patient would be thin without excessive abdominal fat, low muscle mass, minimal hip contracture, and no history of previous hip surgery, as well as without acetabular or femoral deformity.[5,6]

This article highlights the surgical tips and pitfalls of anterior hip replacement using a mobile leg positioner designed by Medacta (Strada Regina, Switzerland). The leg positioner aids the technique by allowing precise control of leg position, allowing hyperextension, adduction, abduction, and rotation of the leg for exposure of the acetabulum and femoral component placement.

Preoperative Setup

Preoperative planning is performed in the usual manner with regard to the implant size, restoration of femoral offset and

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Submitted: 07-Feb-2022 **Revised:** 27-Jun-2022
Accepted: 06-Jul-2022 **Published:** 14-Sep-2022

How to cite this article: Gupta V, Tran P, Arora M. Surgical tips/tricks on minimally invasive anterior hip replacement. J Arthrosc Jt Surg 2022;9:72-6.

leg length, level of the neck cut, head size, and center of rotation, using either hard film or digital X-ray templates. The mobile leg positioner is securely attached to the table. The patient is then transferred to the table in the supine position. Once anesthetized, the foot is padded and secured in a traction boot lined with gel pads or just wrapped with wool firmly. A cushioned perineal support is applied to the table, and the patient's pelvis is brought down to meet it. The perineal support needs to be well padded to avoid injury to the pudendal nerve and genitals. The traction boot is then secured to the AMIS mobile leg positioner, as shown in Figure 1. The patella is then placed in a neutral position; the foot is internally rotated which can be achieved by the leg positioner. No traction is applied to the operating limb, reducing muscle tension and allowing flexion of knee and hip as required.

Tip/trick

Both the arms should be held outward and perpendicular so as to avoid interference in femoral canal preparation and prosthesis placement [Figure 1].

Skin Incision and Initial Exposure

Mark the locations of the greater trochanter and anterior superior iliac spine (ASIS) [Figure 2]. The abdominal and inguinal skin creases should also be marked to define the ideal superior extent of the incision. There should be no creases in the canvas to minimize risk of injury to the patient.

The muscle belly of the tensor fascia lata (TFL) should be palpated, and the interval between it and the rectus femoris was identified. A 6–8 cm longitudinal incision is directly placed over the TFL approximately 2–3 cm lateral to this interval, starting just distal to the inguinal skin crease and parallel to the muscle belly of the TFL. Split the fascia longitudinally over the middle of the muscle belly or anterior third in more muscular patients [Figure 3].

Tip/trick

The lateral femoral cutaneous nerve (LFCN) lies parallel to the incision within the sartorial sheath just before penetrating the fascia, approximately 10 cm distal to the ASIS, and supplies the skin over the anterior and lateral thigh through its branches. To minimize the chances of injury to the LFCN, incision should be carried out through the iliotibial band (ITB) more laterally. During the approach, incising the fascia over the TFL muscle and staying within the TFL sheath (outside of the sartorial sheath) are the key steps to protect LFCN during the approach and throughout the case. However, this simple move can make retraction in muscular patients difficult and lead to a greater chance of inadvertent muscle damage with the retractors.

Deep Exposure

The fascia is gently separated from the underlying tensor muscle both anteriorly and posteriorly. A Beckman retractor is then inserted underneath the fascia with the tensor muscle on the lateral side and the sartorius on the medial side. A safe way to identify the exact location of the interval is

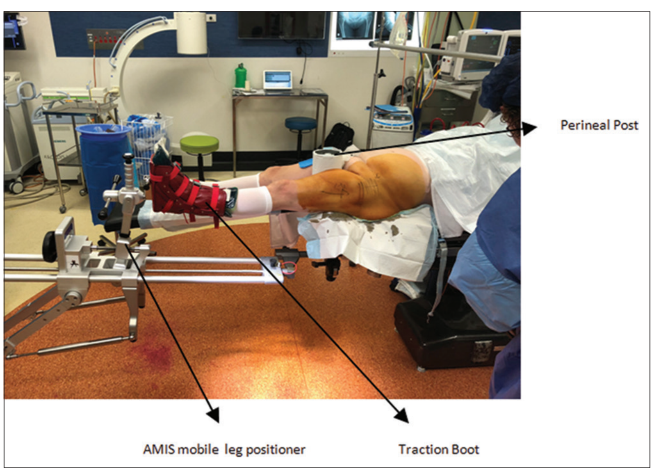

Figure 1: Position of the patient on operating table

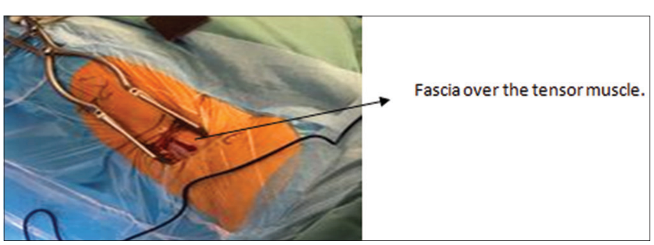

Figure 3: Initial exposure of fascia over tensor muscle

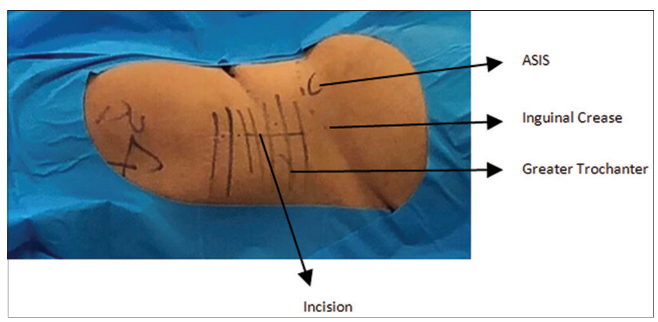

Figure 2: Surgical landmarks. ASIS: Anterior superior iliac spine

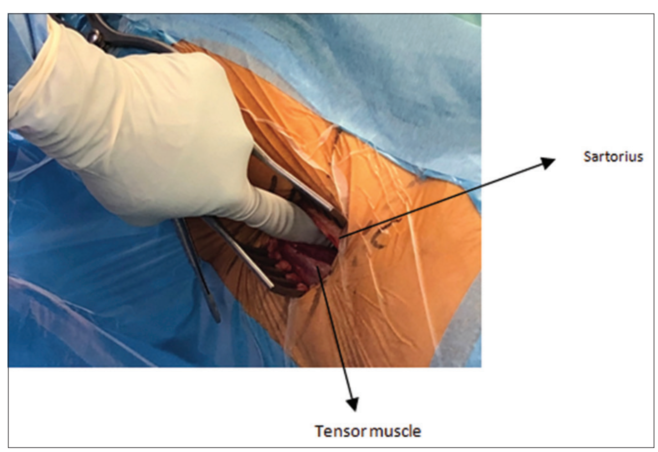

Figure 4: Separating the interval between sartorius and tensor muscle

to gently manipulate with your finger before placing the retractors [Figure 4].

Further dissection through the fat layer and deeper placement of the Beckman retractor will reveal the interval between the rectus femoris and TFL. A shiny aponeurosis is visualized between the medial side of tensor and the lateral side of the rectus femoris. The branches of lateral circumflex arteriovenous bundle lies under this aponeurosis, particularly in the distal aspect of the wound. The aponeurosis is carefully split with a diathermy avoiding damage to the underlying vessels. The circumflex vessel is enclosed in a fatty cellular layer, which is then isolated and cauterizes or cuts between two ligatures [Figure 5].

The Beckman retractor is then placed deeper to expose the capsule. A capsulotomy is made in a triangular fashion, with the apex directed medially. This apex is then elevated off the bone by the electrocautery. A no. 1 vicryl suture is tied to the medial apex to aid in further retraction of the capsule laterally during dissection off the anterior aspect of the femoral neck. After the capsulotomy, two blunt Hohmann retractors are positioned on the superior and inferior aspects of the femoral neck.

Tip/trick

Sometimes, the reflected head of the rectus femoris will hinder visualization of the joint capsule, in which case it can be partially reflected. For beginners, it is advisable to minimally extend the incision distally by 2–3 cm and extend the distal incision of TFL. This will release the muscle and prevent damage to its belly.

Femoral Neck Cut

Following the exposure of the anterior aspect of the femoral neck, an osteotomy of the femoral neck is performed. The best landmark for this is peritrochanteric tubercle which can be traced from the most external part of the neck, at the junction with the greater trochanter. One of the main differences between the anterior approach from other approaches is that the osteotomy of the neck is performed without dislocation of the femoral head, so identification of this landmark is important. One should start the neck cut just above the peritrochanteric tubercle laterally and direct the saw medially about 15° above the intertrochanteric line [Figure 6]. Once the osteotomy of the femoral neck is complete, mild traction and external rotation of the limb using the leg holder allow the separation of the femoral head from the shaft. A corkscrew is placed in the middle of the femoral head and the femoral head is extracted carefully by tilting the corkscrew proximally toward opposite ASIS. It is important to note that hasty removal of the femoral head can damage the surrounding muscles by the sharp edges present at the osteotomy ends.

Important tip

To check the adequacy of the femoral neck cut, the leg can be slowly externally rotated using the leg holder by an unscrubbed assistant, while the surgeon releases the capsule and pubofemoral ligament from the calcar and lesser trochanter using a diathermy. Soft tissue release allows safe external rotation of the leg and palpation of the lesser trochanter and determination of the level of the neck cut.

Once the femoral head is extracted, the Beckman retractor is removed and replaced with a modified Charnley retractor to expose the acetabulum. Both limbs of the Charnley retractor are placed into the hip capsule, to protect the surrounding muscular soft tissue envelop. Introduce the medial blade of the Charnley retractor and place it below the anterior capsule at the junction of the capsule and acetabulum. With one hand, the medial blade of the AMIS retractor is held tightly while the adjustable lateral blade is positioned over the laterally turned capsular flap. A small gauze placed underneath the capsular flap and suture tie will help protect the underlying TFL.

Acetabular Preparation

The labrum is excised with a long handle blade. The ligamentum teres is excised with a long tip diathermy. Acetabular reaming begins with a 42- or 44-sized reamer. The true acetabular floor is identified. Gradually, ream to the desired size. Size and position can be checked with the aid of intraoperative fluoroscopy. After adequate preparation of the acetabulum, a trial component is placed in the socket to

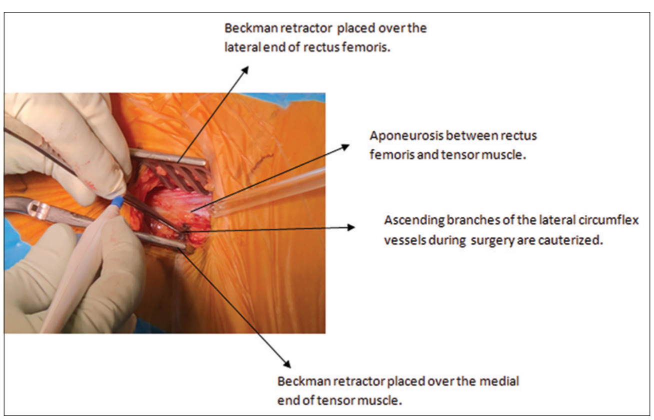

Figure 5: Exposing rectus femoris and separated

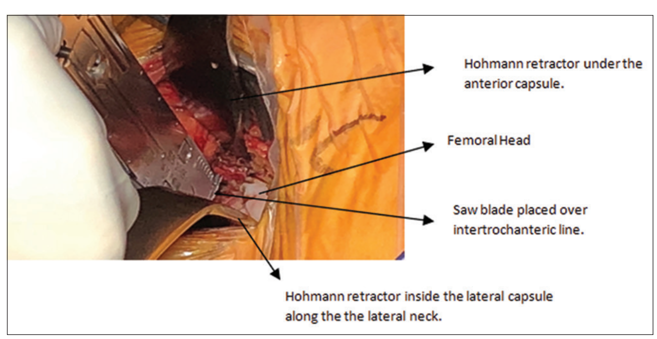

Figure 6: Femoral neck exposed and neck cut performed

confirm the size and fit. The definitive acetabular prosthesis is then impacted and checked for stability. This is followed by the insertion of the liner. A final check of the cup and liner can be confirmed on X-ray.

Tip/trick

Surgeons who are new to the supine position often place the cup at an open inclination and anteverted position. The position of the cup inserter is close to parallel to the floor. The use of fluoroscopy improves component positioning.

Femoral Exposure (Traction + External Rotation + Adduction + Hyperextension)

Once acetabular preparation is complete, all focus should be on the positioning of the femur for canal preparation and prosthesis placement. The ideal position of the leg for adequate canal preparation is with the foot rotated to around 180°. To facilitate this, release is performed first distally of the pubofemoral ligament and capsule near the calcar and second proximally to the iliofemoral ligament. Externally rotating the foot to around 180° will result in rotating the femur to 90°. This is the desired position for the femoral canal preparation and prosthesis placement.

It is important that the surgeon controls the external rotation of the leg by placing one hand on the knee. Rotation is performed in 30° increments, releasing the pubofemoral and iliofemoral ligament incrementally, until 180° is reached.

Use a blunt bone hook that is placed over the tip of greater trochanter to lateralize the proximal femur, to make sure that the greater trochanter is free from and not trapped posterior to the ischial tuberosity. Lowering the leg without this check can result in femoral fracture [Figure 7].

Tip/trick

1. Forceful external rotation of the femur can cause a lower extremity fracture particularly in the elderly and osteoporotic patient. Therefore, forceful external rotation should be avoided. To assess the adequacy of soft tissue release, place the bone hook in the femoral canal and try to pull the femur past the acetabulum. If the femur fails to pull up, it is worth repeating soft tissue release again

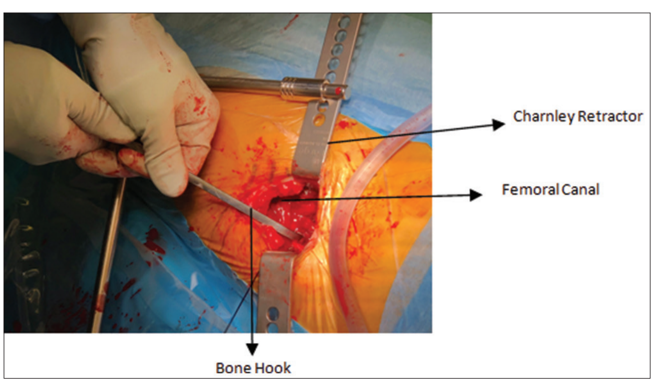

Figure 7: Lifting proximal femur with bone hook to get an adequate view of femoral canal for broaching

2. It is to be noted that the piriformis and obturator internus tendons insert on the inner surface of the greater trochanter. The obturator internus tendon typically lies medial to the tip of the greater trochanter. Further release of the capsule from the medial trochanter tip coupled with the partial or total release of internus tendon provides full exposure of the medial greater trochanter tip and enhances the femoral mobility. This is particularly useful in patients with short neck and longstanding arthritis in whom the hip is generally stiffer in external rotation.

Femoral Broaching and Trialing

Lower the externally rotated leg to the ground. At this stage, the leg holder is at its lowest position close to the floor. Place the sharp tip of curved Hohmann bone lever above the tip of the greater trochanter and outside the hip. This allows further elevation of the femoral neck. A medially placed sharp Hohmann can provide a lateral force. Placing the patient in the Trendelenburg position by tilting the operating table aids in femoral exposure, by allowing maximum hyperextension of the hip for broaching and trialing.

Preparation of the femoral canal begins with a Charnley curette, rather than a box cutter. Avoid using a box cutter for canal preparation as this tends to violate the posterior cortex of the femur. A curved starter rasp defines the initial passage and angle of the femoral canal and guides the version of broaching. Sequential broaching is done until a suitable size is attained, and this can be checked under fluoroscopy.

Tip on broaching

The basic principle of the technique is to find the canal direction with careful and gentle use of the starter rasp. Never hammer the starter rasp as this can create a false canal.

Trialing

After placing the appropriate trial neck and head on to the trial component, the leg is internally rotated and lifted off the ground using the leg holder. It helps “shake” the knee to rotate it.

The hip is then reduced. A check of the offset and leg length is confirmed using image intensifier. Final implantation of the prosthesis can then be performed.

Intraoperative fluoroscopy helps in establishing limb length equality as well as offset by comparing the contralateral side, while trialing (usually identifying the relation of the lesser trochanter to the ischium) or a comparative image can be taken, printed, and then placed over the image of the contralateral hip joint).

Wound Closure

The joint capsule is to be repaired loosely as tight anatomical repair can cause iliopsoas irritation. Running sutures are used to close the ITB, being careful not to catch the superficial branches of the LFCN.

Complications

The direct anterior approach is a very safe approach in well-trained hands with potential benefits. Since this approach is muscle sparing, one should not expect to see complications involving muscular damage, especially dislocation. By utilizing this approach, the greatest risk is damage to the LFCN due to the proximity to the surgical dissection and the variation in the anatomy of the superficial branches. As discussed earlier, this kind of damage can be minimized by placing the skin incision as laterally as possible and by ensuring that the medial subcutaneous fat pad remains untouched during the whole procedure.

Note

In obese patient, it is imperative to stress on postoperative wound care to avoid delayed wound closure.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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