Review Article

Innovative Multi-Modal Protocol based Therapy (IMMPT) to improve functional outcomes after Total Knee Arthroplasty (TKA)

Anil Bhave, P.T.[1], Michael A Mont, MD[2], Tanner McGinn, B.S.[1], Morad Chughtai, M.D.[2]

[1]Rubin Institute for Advanced Orthopedics,Sinai Hospital, 2401, West Belvedere Avenue Baltimore, Maryland

[2]Cleveland Clinic, Dept. of Orthopedic Surgery, Cleveland Clinic Main Campus 9500 Euclid Avenue, Cleveland, OH 44195

Corresponding Author: Anil Bhave, PT, Rubin Institute for Advanced Orthopedics, Rehabilitation Dept. Sinai Hospital of Baltimore, 2401 West Belvedere Avenue, Baltimore, Maryland 21215
E-mail: abhave@lifebridgehealth.org; anilbhave@yahoo.com

Introduction

Knee stiffness and muscle weakness are frequent complication after primary total knee arthroplasty (TKA), and has been reported in up to 25% in some series.[1,2] It can impair ability to perform activities of daily living.[3-9] Physical therapy after TKA plays a major role in helping patients achieve adequate range-of-motion and strength. If physical therapy fails to improve ROM (to > 90° flexion) beyond the 6 to 8 week period postoperatively, amanipulation under anesthesia (MUA) is considered as an option.[2,3,5,10,11] Manipulations under anesthesia may improve knee stiffness.[1-4,11,12-17] However, complications following MUA include, supracondylar fracture, patellar or quadriceps tendon avulsion, and possible increased risk for revision.[2,5,13] Repeat surgical procedures can have significant economic burden on the healthcare system, the patient, and the patient's family. In addition to knee stiffness, persistent muscle weakness of the quadriceps and hip abductor muscles can lead to significant limitation in functional activities. Therefore, it is critical to create physical therapy pathways to optimize conservative measures in order to avoid riskier, and costly options.

The goal of outpatient physical therapy following a TKA is to return the patient to functional activity. Typically, the outpatient regimen begins within 1 to 2 weeks of surgery. The standard of care uses exercise modalities in combination with manual therapy protocols. The innovative multimodal physical therapy (IMMPT) approach at our facility uses these approaches while incorporating newer modalities to improve range of motion (SPS bracing and Astym technique) and muscle strength (NMES and EAO bracing). The timing of application of the multi-modal modality approach is as critical as use of it for optimum outcomes.

At our Institution a strict protocol driven approach is used on all patients after TKA in contrast to that when our patients go for therapy in the community. Based on literature review and our own chart review of approximately 500 patients, therapy practices in the community tend to use atypical modalities that we do not use at our Institution. This approach of non-standardized therapy in the community without strict enforcement of protocols leads to increased rate of MUA, persistent quadriceps weakness and reduced ROM.

Standard-of-care Physical Therapy Protocol at our Institution

A typical postoperative course following a primary total knee replacement is broken into either 3 or 4 different phases but the time guidelines are as follows: 1) Acute inpatient physical therapy typically between 1-3 days; 2) one to 6 weeks of outpatient physical therapy focusing on increasing quadriceps strength, passive ROM, and ambulation without assistive devices; and 3) Six to 8 weeks returning to typical everyday functionality.[10,14]

In the acute phase patients receive first therapy visit day of surgery by 4 PM. Physical Therapist focus on bed mobility and transfers, isometrics and education. In the acute phase day two and three are focused on continuing to work on safe transfers, isometrics, Slide and flex and tighten and extend (SAFTE) exercise. SAFTE are very effective way of obtaining active and active assisted flexion as well as quadriceps and hip extensor recruitment in extension. SAFTE exercises are performed on a sliding board and a gait belt is used across the ankle joint, patients hold the other end of gait belt to flex the knee and resist knee extension. This type of exercise is shown to be very effective and can eliminate use of CPM modality. Patients that exhibit active extension lag greater than 15-20 degrees are given a knee brace locked in full extension for transfers and ambulation. Patients and family members are educated about ice therapy and use of compression and elevation to minimize swelling and edema. By day 3 most patients are discharged home.

In the sub-acute phase, week 1 through 6 weeks, therapy is performed 2 to 3 times a week. Each session of therapy is 1 hour duration, out of which 30 minutes patient receives one on one attention by the therapist, for manual therapy and mobilization. The other 30 minutes are spent in modalities and therapy-aid supervised therapeutic activity. The emphasis is on achieving range of motion and muscle recruitment strategies. Joint mobilization grade 2 and 3 as well as patellar multidirectional mobilization are applied. Careful examination of hamstring length using popliteal angle and gastrocnemius length using Silverskjold test are performed; and if these muscle are tight, appropriate stretching is performed. Soft tissue mobilization of distal IT band and short head of biceps is recommended. Some of the therapeutic exercise include stationary bike, shallow step climbing, standing isometric ROM exercises, balance training, sit to stand exercises, low level followed by higher lever closed chain resistance activities.[12] Shallow wall slides at 45 to 60 degrees of flexion and forward lunge with bilateral support for safety are performed under therapist supervision. Hip abductor strength is a critical component of functional activities and is evaluated and if found weak proper strengthening exercises are performed. Gait training to normalize heel toe gait progression, and use of small objects placed on the floor as obstacles to initiate correct knee flexion during the swing phase the gait cycle. Backward walking with therapy supervision allows for full extension in gait. Moist heat is applied before therapy to improve tissue pliability of the dense connective tissue (DCT). Ice and compression therapy are used after therapy is performed. During both extension and flexion knee mobilization, the patient's patella should be mobilized. It is recommended to mobilize patella superiorly for extension mobilization and inferiorly for flexion mobilization.

Week 6 through 10 -12 therapies is performed 2 -3 times a week. Patients that are progressing well are encouraged to do therapy twice week while patients that are not progressing continue 3 times a week. Outpatient therapy is focused on improving pain free active knee ROM to 0 to 130 degrees, overall muscle power of the extremity to minimum of 4+/5 muscle strength grade, to independently ambulate in the community, go up and down stairs with normal sequence, and gradually return to non-impact recreational and sport activities. In terms of therapeutic exercise progression to full weight bearing, closed chain exercises, concentric and later eccentric quadriceps exercises, and 6 and 8 inch step up are encouraged. In addition, ensuring that patient's engage both legs equally in all weight bearing closed chain activities such as shallow and deep squats, sit to stand etc is done through use of feedback using bathroom weighing scales. Excessive use of non-surgical limb during weight bearing activities has shown to rapid progression OA of the non-operated limb. Typical activities that are safe for patients after TKA include bicycling, swimming, golf, doubles tennis, low impact aerobics, gardening and ballroom dancing. Certain activities such as racquetball, squash, soccer, gymnastics, running, and sprinting are not recommended for patients after TKA.

IMMPT Physical Therapy Protocol at our Institution

This protocol was originally developed and implemented at our Institution by authors (AB and MAM) because of variable success of commonly utilized rehabilitation modalities.[15,16] We first developed a standardized protocol driven approach at our center as compared to atypical and inconsistent therapy practice that may be the community therapy. We added Multi-modal approach to our protocol to further to reduce variability of our results. This variability in outcomes in primary TKA is due factors such as patients pre operative status are not similar. Patients may have pre operative flexion or extension contractures, significant quadriceps weakness, obesity, use of atypical analgesics leading to poor pain tolerance, and adjacent joint problems. It has been shown that up to 35% patients may have abnormal inflammatory profile leading to variable level of pain and stiffness after TKA surgery.[18] In addition there are several general health, gender, and age related issues that can affect TKA outcomes. It is observed that patients with BMI greater than 30 struggle with ROM and strength recovery.[19,20] Younger female and athletic male patients specifically pose greater challenge in achieving ROM. Patients who are chronic smokers or have type II Diabetes Mellitus have poor tolerance to therapy. The IMMPT protocol was developed for a clinical need to achieve improved ROM and strength results when patients are not progressing optimally in their rehabilitation. Not only the type, and specificity of the modality matter but also timing of when the modality during the recovery phase is applied is also equally important. IMMPT treatment strategy can be generally categorized into 1) range-of-motion and 2) muscle strength enhancement strategies.

Range-of-motion strategies

The three modalities were used for range-of-motion in the IMMPT protocol (Table 1) are, customized knee device braces (CKD)(Figure1), and static progressive stretching (SPS) by joint active system braces (JAS) (Joint Active Systems, Inc. 2600 South Raney, Effingham, IL 62401) (Figure2).

Astym therapyv (Performance Dynamics Inc, 400 North High Street, Suite 320, Muncie,

Figure 1: Customized Knee Device (CKD) is made out of polyester fiber glass casting material with aluminum hinges. Theraband in figure of eight is used across hinges for applying extension force across the knee joint. CKD is removable, custom fitted and low cost.

Figure 2: Knee flexion and extension Joint Active Systems (JAS) devices utilizing static progressive stretching technique. Patients wear JAS device 30 minutes 3 times a day

Indiana 47305), (Figure 3) utilizes handheld instrumentation, applied topically, to locate underlying dysfunctional soft tissue and then transfer particular pressures and shear forces to

Figure 3: Astym therapy is performed by certified clinician, which involes topical application of a series of hand-held instruments specifically designed to stimulate areas of dysfunction and scarring. Once a potential area is located, the provider applies appropriate shear force and pressure to initiate a reparative cellular response in dysfunctional tissue.

the dysfunctional tissue through specific protocols and patterns developed from scientific and clinical studies. The Astym instrumentation is designed to assess the presence of dysfunctional tissue by amplifying the tactile sensation of the underlying texture of the soft tissues in order to provide the treating clinician with indications where rough or improperly organized tissue is located. Once an area of potential dysfunctional tissue is located, the clinician applies appropriate pressures and shear forces to that tissue, aimed at initiating a reparative cellular response in dysfunctional tissue. Astym therapy is used to treat the medial and lateral patellar retinaculum, the patellar tendon, the proximal rectus femoris muscle insertion, the hamstring muscles, the gastrocnemius-soleus muscle complex, the distal ilio-tibial band, the quadriceps muscle, including the quadriceps tendon, and the Achilles tendon.

Patients with knee flexion contracture greater than 15 degrees or flexion deficit of less than 90 degrees after 2 weeks of Astym therapy are fitted with a brace for static progressive stretch. Specifically, splinting with the custom knee device (CKD) is used for improving extension and SPS using Joint Active System devices are used for improving flexion (Table 1). The patients are taught the correct use of the devices and used them for 30 minutes, 3 times a day. Reduced ROM after TKA is caused by early fibrosis of dense connective tissue, and this tissue responds well to SPS type of stretching protocol as compared to dynamic or spring loaded braces. In addition SPS braces provide adequate force across the joint for tissue deformation, which is critical for improving ROM.

In addition to CKD and JAS device both improving extension and flexion respectively we use Extension Assist Orthosis (EOS) called Guardian Sports Ext Brace, (Ongoing Care Solutions Inc.

Table 1: Modalities used for in Protocol

Clinical Problem	Modality	Timing	Duration and use
1) Quadriceps lag >15 degrees in straight leg raise, at intake for Outpatient PT	NMES treatment in clinic	Day one of PT	Until quad lag less than 5 degrees in SLR 20 minutes every time in PT
2) Quadriceps Lag > 15 and poor quad activation in quad setting	Home NMES unit	One week of Outpatient PT	Until quad lag less than 5 degrees in SLR, 20 minutes BID/ daily
3) Quadriceps lag, and difficuly, in walking and stairs	GuardianSport Brace, Extension assist orthosis (EOS)	After 3-4 weeks of Outpatient PT	up 3 months or until safely ambulating and be able to go up and down one flight Daily use for minimum 3 hours per day when up and about
4) Knee flexion contracture >15 degrees	1) CKD fitting, Customized Knee Device 2) EOS Guardian Sport Ext	4 weeks of PT	Until Knee flexion contracture less than 5 degrees. 30 minutes 2 to 3 times daily
5) Knee flexion ROM less than 90 degrees	ASTYM(Augmented soft tissue stimulation therapy)	2-3 weeks from initiation of Outpatient PT	8 to 12 session from start date or until AROM greater than 120 degrees
6) Knee flexion ROM less than 90 degrees	SPS using Joint Active System Knee flexion device	Within 4 weeks of Outpatient PT	AROM greater than 120 degrees

6551 43rd Street North, Unit 1403 Pinellas Park, FL 33781) (Figure 4) to improve knee extension. Unlike CKD and JAS, which are static braces and are used by the patient in bed or in sitting only. EOS sport Ext brace is a dynamic brace. It has embedded elastic bands that apply extension stretch and assist every step patients takes. This device

Figure 4: Guardian Sports Ext Brace with 4 pneumatic bladders, and extension assist bands. Patients are encouraged to wear for minimum of 3 to 4 hours per day. This brace is utilized for patients with Knee flexion contracture greater than 15 degrees and quadriceps activation deficit

allows for active stretching of the tight posterior structures in addition to quadriceps activation and strengthening.

The Guardian sport extension brace has 4 pneumatic bladders, two are medial and lateral over the knee joint condyle for custom fitting and reducing brace migration and the other two are placed posterioly over proximal tibia and anterioly over distal femur. These two antero-posterior bladders once inflated apply an extension force across the knee joint in addition to extension assist bands. Correct use of this brace for 2 to 3 hours per day when patients are ambulatory leads to up to 3000 extension stretches and quad activations per day. The power of this brace is numbers of repetitions and it is a wearable technology.

Muscle Strength Enhancement Strategies

Following unique modalities are used for muscle strength enhancement as part of the IMMPT (Table 1), and those are SAFTE (Slide and flex and tighten and extend) exercises, neuromuscular electrical stimulation (NMES) of quadriceps muscles (Fig 5), and EOS by Guardian sports bracing. SAFTE

Figure 6: Guardian sport brace, This brace is employed in patients with persistent quadriceps weakness and less than 10 degrees of knee flexion contracture. Patients are encouraged to wear it minimum 3 hours per day when active

are generally performed in sets of ten repetitions, 5 to 6 times a day, in early post surgical phase as outlined in a previous study.[6]

Patients who had quadriceps lag during a straight leg raise test or poor contraction in the long leg position received a NMES unit to be used at home for 20 minutes, two times a day6 in addition to use in therapy. Patients are progressed in NMES from quad set position to short arc quad position to long arc positioning. In the late recovery phase, we employed high flexion knee activities such as squats and kneeling, to address quadriceps strength through the entire arc of flexion range-of-motion. In addition, an EOS using Guardian sports brace (Ongoing Care Solutions Inc.6551 43rd Street North, Unit 1403Pinellas Park, FL 33781) (Fig 6) is

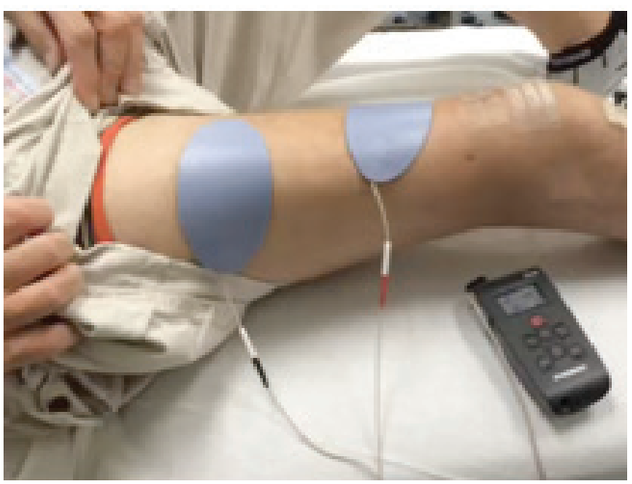

Figure 5: NMES in quad setting position, patients are encouraged to increase intensity every 2 minutes and goal is to always do maximally tolerated intensity. NMES protocol is 300 to 400 microseconds in pulse width, 10 seconds on, 30 seconds off, and pulse frequency of 40 to 75pulses per second.

used to improve quadriceps and hamstring strength in patients who continued to have difficulty with quadriceps activation (deficit in functional activities such as walking, stair climbing, etc.). This unique brace allows for muscle strength augmentation just by walking in the brace.

Patients are requested to use brace minimum of 3 hours per day when active. The extension assist bands embedded in the brace promote appropriate loading of the quadriceps and hamstring muscle in gait to promotemuscle activation and strength.

Summary

Employing standardized protocol and use of IMMPT when patients are progressing poorly has led to improvement in our outcomes after TKA. This has led to fewer MUA procedures at our center for both, non obese less than 30 BMI, and obese greater than 30 BMI. Reduced rate of manipulation (MUA) may reduce revision TKA surgery. In addition greater number of patients are achieving optimal range of motion and strength, which leads to improved patient satisfaction, and return to normal function.

References

1. Issa K, Rifai A, Boylan MR, Pourtaheri S, McInerney VK, Mont MA. Do various factors affect the frequency of manipulation under anesthesia after primary total knee arthroplasty? Clinical orthopaedics and related research 473(1): 143, 2015.
2. Choi HR, Siliski J, Malchau H, Freiberg A, Rubash H, Kwon YM. How often is functional range of motion obtained by manipulation for stiff total knee arthroplasty? International orthopaedics 38(8): 1641, 2014.
3. Keating EM, Ritter MA, Harty LD, Haas G, Meding JB, Faris PM, Berend ME. Manipulation after total knee arthroplasty. The Journal of bone and joint surgery American volume 89(2): 282, 2007.
4. Fox JL, Poss R. The role of manipulation following total knee replacement. The Journal of bone and joint surgery American volume 63(3): 357, 1981.
5. Werner BC, Carr JB, Wiggins JC, Gwathmey FW, Browne JA. Manipulation Under Anesthesia After Total Knee Arthroplasty is Associated with An Increased Incidence of Subsequent Revision Surgery. The Journal of arthroplasty 30(9 Suppl): 72, 2015.
6. Seyler TM, Marker DR, Bhave A, Plate JF, Marulanda GA, Bonutti PM, Delanois RE, Mont MA. Functional problems and arthrofibrosis following total knee arthroplasty. The Journal of bone and joint surgery American volume 89 Suppl 3: 59, 2007.
7. Ritter MA, Campbell ED. Effect of range of motion on the success of a total knee arthroplasty. The Journal of arthroplasty 2(2): 95, 1987.
8. Padua R, Ceccarelli E, Bondi R, Campi A, Padua L. Range of motion correlates with patient perception of TKA outcome. Clinical orthopaedics and related research 460: 174, 2007.
9. Du H, Tang H, Gu JM, Zhou YX. Patient satisfaction after posterior-stabilized total knee arthroplasty: a functional specific analysis. The Knee 21(4): 866, 2014.
10. Yercan HS, Sugun TS, Bussiere C, Ait Si Selmi T, Davies A, Neyret P. Stiffness after total knee arthroplasty: prevalence, management and outcomes. The Knee 13(2): 111, 2006.
11. Pariente GM, Lombardi AV, Jr., Berend KR, Mallory TH, Adams JB. Manipulation with prolonged epidural analgesia for treatment of TKA complicated by arthrofibrosis. Surgical technology international 15: 221, 2006.
12. Issa K, Banerjee S, Kester MA, Khanuja HS, Delanois RE, Mont MA. The effect of timing of manipulation under anesthesia to improve range of motion and functional outcomes following total knee arthroplasty. The Journal of bone and joint surgery American volume 96(16): 1349, 2014
13. Ghani H, Maffulli N, Khanduja V. Management of stiffness following total knee arthroplasty: a systematic review. The Knee 19(6): 751, 2012.
14. Chughtai M, Mont MA, Cherian C, Cherian JJ, Elmallah RD, Naziri Q, Harwin SF, Bhave A. A Novel, Nonoperative Treatment Demonstrates Success for Stiff Total Knee Arthroplasty after Failure of Conventional Therapy. The journal of knee surgery, 2015.
15. Moffet H, Collet JP, Shapiro SH, Paradis G, Marquis F, Roy L. Effectiveness of intensive rehabilitation on functional ability and quality of life after first total knee arthroplasty: A single-blind randomized controlled trial. Archives of physical medicine and rehabilitation 85(4): 546, 2004.

16. Kumar PJ, McPherson EJ, Dorr LD, Wan Z, Baldwin K. Rehabilitation after total knee arthroplasty: a comparison of 2 rehabilitation techniques. Clinical orthopaedics and related research (331): 93, 1996.

17. Wied C, Thomsen MG, Kallemose T, Myhrmann L, Jensen LS, Husted H, Troelsen A. The risk of manipulation under anesthesia due to unsatisfactory knee flexion after fast-track total knee arthroplasty. The Knee 22(5): 419, 2015.

18. Brander VA, Stulberg SD, Adams AD, Harden RN, Bruehl S, Stanos SP, Houle T. Predicting total knee replacement pain: a prospective, observational study. Clinical orthopaedics and related research (416): 27, 2003.

19. Gadinsky NE, Ehrhardt JK, Urband C, Westrich GH. Effect of body mass index on range of motion and manipulation after total knee arthroplasty. The Journal of arthroplasty 26(8): 1194, 2011.

20. Issa K, Kapadia BH, Kester M, Khanuja HS, Delanois RE, Mont MA. Clinical, objective, and functional outcomes of manipulation under anesthesia to treat knee stiffness following total knee arthroplasty. The Journal of arthroplasty 29(3): 548, 2014.

★ ★ ★