

Microstructural Changes of Tensor Fasciae Latae and Gluteus Medius Muscles Following Total Hip Arthroplasty: A Prospective Trial

Mikrostrukturální změny m. tensor fasciae latae a m. gluteus medius po totální náhradě kyčelního kloubu: prospektivní studie

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ABSTRACT

PURPOSE OF THE STUDY

Although total hip arthroplasty (THA) is one of the most successful orthopedic operations, the soft tissue trauma towards the periarticular musculature during surgical approaches remains a critical concern. However, the actual microstructural proof of muscle trauma on the level of the myofiber due to the surgical approach has never been claimed.

MATERIAL AND METHODS

Patients undergoing THA were prospectively enrolled and either operated by a direct lateral (DL) or a anterolateral minimally invasive approach (ALMI). Intraoperatively and at 6 months follow-up a needle biopsy was taken from the gluteus medius muscle and the tensor fasciae latae. Pre- and post-operative fiber diameter and composition, of gluteal medius muscle (GMM) and the tensor fasciae latae muscle (TFLM) were compared in both surgical approaches.

RESULTS

A total of 19 patients (12 F; 7 M) were included in this study. The average pre-operative fiber diameter or fiber type composition did not differ significantly in the GMM and TFLM, nor did it vary among patients with different approaches. The muscle fiber diameter significantly increased post-operatively in the TFLM, in both, the DL ($p = 0.043$) and the ALMI ($p = 0.043$) approach. There was a trend towards more pronounced muscle fiber changes in the DL (TFLM: $p = 0.077$; GMM: $p = 0.150$), compared to the ALMI.

DISCUSSION AND CONCLUSIONS

Our results show microstructural changes to the periarticular musculature following THA by a compensatory hypertrophy of the TFLM and GMM. These adaptations directly next to the surgical trauma were observed in DL and ALMI.

Key words: total hip arthroplasty, skeletal muscle, muscle biopsy, iatrogenic trauma, muscle scar.

INTRODUCTION

Total hip arthroplasty (THA) is known to significantly reduce pain, improve function, increase patient satisfaction and quality of life (17). Nevertheless, one of the remaining concerns is the surgical trauma towards the soft tissue, especially the periarticular musculature. A large body of evidence shows the clinically relevant injury, significantly reducing patient outcomes. Holm et al. showed a significantly impaired hip muscle strength and leg power strength after THA compared to pre-operative force (3). The muscle strength of all functional movements of the hip joint, are affected: flexion, extension, abduction and adduction (4, 5, 19). Furthermore, the macrostructural

post-surgical changes in periarticular muscles have been extensively studied in MRI. Interestingly, a high correlation of MRI findings and functional muscle power analysis as well as post-operative pain were confirmed (21, 22).

In Europe due to lower dislocation rates lateral approaches are preferred over posterior approaches. The classical direct lateral approach (DL) for THA was first described by Hardinge and gains access through splitting of the anterior part of the gluteus medius muscle (2). An excellent exposure of the joint and lower dislocation rates than with the posterior approach were the reason, why a lot of surgeons have employed the approach ever

since. The disadvantage of the DL is the injury to the anterior part of the gluteus medius muscle. In order to spare soft tissue and reduce muscle injury, minimally invasive approaches have been introduced into THA surgery (1). The anterolateral minimally invasive approach (ALMI), a modified Watson-Jones approach, has been described by Bertin and Rottinger in 2004 (1). Thereby an intermuscular access between the gluteus medius muscle (GMM) and tensor fasciae latae muscle (TFLM) is performed. Minimally invasive approaches in THA are deemed to be superior to transgluteal approaches concerning earlier rehabilitation and return to mobility, less post-operative pain and blood loss (20). However, remaining concerns of minimally invasive approaches are implant malpositioning, nerve and vascular injury and insufficient intra-operative visualization (13, 24).

A recent study compared the extent of muscle injury on post-operative MRIs after ALMI and DL. A reduced muscle trauma in the minimally invasive group could be shown (12). Although these structural changes of the periarticular musculature have been advocated on the basis of radiographic studies, to our knowledge, no study proved a muscular adaption to the intraoperative trauma on a microstructural level following THA. Therefore we compared histologically the periarticular musculature (GMM and TFLM) pre- and post-operatively after THA using DL as well as ALMI. The hypothesis was that both muscles would show an increase in fiber diameter after THA due to post-operative compensation of the iatrogenic trauma.

MATERIAL AND METHODS

The study was approved by the institutional review board (EA 1/087/07). Prior to any inclusion, written informed consent was obtained from all patients. All patients were prospectively enrolled and diagnosed with degenerative hip arthritis. Exclusion criteria were mental or physical disability, previous hip ipsilateral surgery, rheumatoid arthritis, muscle disease and anticoagulant therapy.

Intra-operatively all patients received an open needle biopsy of the GMM and TFLM of the side of THA at the start of the surgery after skin opening. (Bard Magnum, Bard Biopsy Systems, Tempe, USA) The area of biopsy for the GMM was 5 cm proximal to the greater trochanter, cranial to the direct operative approach trauma, and for the TFLM 5 cm distal to the anterior iliac spine. A detailed description of the modified direct lateral and ALMI can be found in a previous publication (12). In all patients a cementless tapered titanium straight stem (SL-PLUS, S&N or Troja, Aesculap, Tuttlingen, Germany) and a press-fit or threaded cup (Allofit, Zimmer, Inc, Warsaw, USA or BICON-PLUS, Smith and Nephew, London, UK) was utilized. Post-operative care was similar in all patients and did not differ to previously described regimes (12). All patients experienced the same standardized postoperative care and the same rehabilitation. Physical therapy started on the first postoperative day. The goals of therapy were to enable the

patients to independently transfer, ambulate with full weightbearing using two crutches, and negotiate stairs. All patients were transferred after successful completion of wound healing to a rehabilitation clinic for a 3-week standardized recovery program, including exercises for the entire lower extremity, the ankle, the knee, and all the muscles surrounding the hip. The goals for the patients were to regain full range of motion/flexibility, strength and endurance, and nearly all proprioception. Crutches were used for at least 6 weeks, depending on the preoperative muscular condition of each patient. No further therapy was provided after the rehabilitation program. At 6 months post-operatively patients underwent clinical follow-up examination including a physical examination, and an ultra-sound-guided needle biopsy of the GMM and TFLM. The biopsy was harvested from the same sites as the intraoperative biopsies.

Histology

Cryosections of fine-needle biopsies were cut cross-sectional. Fiber diameter of the GMM and TFLM were measured on hematoxylin and eosin staining, at a minimum of 200 fibers per muscle of representative areas of the muscle sample. Additionally, immunohistological staining for fast- and slow-myosin fiber type evaluation was performed. The staining procedure was previously established and applied for cryosections (23). Briefly, sections were 30-min air-dried, then fixed in cooled acetone and washed in PBS. Then, sections were incubated in horse serum and followed by primary antibody staining (anti-myosin fast, clone My 32 (1:4000, #M4276) or monoclonal mouse anti-myosin slow (1:10 000, #M8421), Sigma). Samples were washed and secondary antibody applied (anti-mouse, rat absorbed, Vector). Finally, avidin-biotin-complex was applied and nuclei were stained (Mayer Haemalaun method). The total muscle was analyzed by a Leica DMRB light microscope (Leica, Wetzlar, Germany) equipped with an AxioCam MRc (CarlZeiss, Göttingen, Germany). Images were evaluated by the provided software (KS 400, Version 3.0, CarlZeiss, Göttingen, Germany).

Statistical evaluation

Pre- and postoperative continuously and normally distributed variables were compared using Mann-Whitney U test. The non-normally distributed variables (scores) were compared with the Wilcoxon test. Statistical analysis was performed by SPSS® (Version 19; SPSS Inc., Chicago, IL).

RESULTS

A total of 19 patients (12 F; 7 M) were included in this study. All patients were diagnosed with degenerative hip arthritis. Eight patients received a mini-open approach and eleven patients a DL. The average age was 63 years in the mini-open group and 68 years in the DL group ($p = 0.363$). All patients were operated by three attending surgeons at a single institution (TW, ST and CP). The average operation time was not significantly different in

Table 1. Mean pre- and post-operative muscle fiber diameter and type distribution including all samples of the medial gluteal muscle and tensor fasciae latae muscle according to the surgical approach

		Fiber diameter			Fiber Type (Fast / Slow)		
		Pre-OP	Post-OP	p-value	Pre-OP (%)	Post-OP (%)	p-value
GMM	ALMI	54.3	55.4	0.916	23.6 / 76.4	23.4 / 76.6	0.753
	DL	57.9	65.7	0.237	22.9 / 77.1	15.6 / 84.4	0.310
TFLM	ALMI	59.2	73.0	0.043*	29.0 / 71.0	41.9 / 58.1	0.080
	DL	55.5	93.3	0.043*	27.9 / 72.1	36.2 / 63.8	0.345

both, DL and ALMI, groups ($p = 0.961$). A total of 56 needle biopsies were stained and analyzed. 20 histological samples were not included in the final evaluation due to non-representative fibrous or fatty fine needle biopsies.

Histological analysis of all pre- and post-operative data

Pre- and post-operative samples of the gluteus medius and the tensor fasciae latae muscle from 19 patients were analyzed. The pre-operative fiber diameter (GMM: $p = 0.409$; TFLM: $p = 0.770$) and type distribution (MHC type I/II) (GMM: $p = 0.745$; TFLM: $p = 1.000$) did not significantly vary among patients. The pre-operative and post-operative fiber diameter and type distribution according to the approach of the GMM and TFLM are depicted in table 1. Significant changes in the fiber diameter of the TFLM could be observed in both approaches (DL: $p = 0.043$; ALMI: $p = 0.043$)

DISCUSSION

The results of this study indicate that microstructural changes in the periarticular musculature are present after THA via both, DL and ALMI. For the first time, we were able to show changes of the periarticular musculature, following THA on a microstructural level and surprisingly the hypothesis was confirmed for the TFLM. We analyzed the area directly next to the surgical approach, giving insights into compensatory muscle adaptations and indirect muscle trauma.

Due to sarcopenia, fatty degeneration and atrophy, muscle strength is physiologically decreasing in the aging population. Therefore, an additional trauma to the muscle, as paralleled by surgical approaches, reduces the functionality even further and may lead to permanent deficiencies. The vulnerability of the elderly has been suggested by Muller et al. (11). It is important to note that in patients with degenerative osteoarthritis the muscle function is already significantly reduced compared to a healthy cohort (7, 8). The importance of minimizing the muscle trauma intra-operatively becomes apparent in cases of post-operative complications related to muscle weaknesses. A common post-operative complication of periarticular muscle weakness after THA is falls. Studies could show that the fall-rate is independent from the post-operative physiotherapeutic regimen (6). This indicates that one of the predisposing factors could be directly related to the operation itself. Interestingly, implant type did not influence muscle weakness after THA (25). However, the authors did not correlate the muscle strength with the surgical approach, which could

have shown an influence on the fall rate due to a different extent of periarticular muscle trauma. MRI has been shown to be an effective tool to evaluate muscle alterations after THA. A study by Pfirrmann et al. showed that MRI correlates with the clinical outcome of patients (16). Fatty degeneration, muscular atrophy, edema and decreased cross-sectional areas have been observed on MRI in parallel to unsatisfying clinical outcome after THA. MRI studies identified differences in the extent of periarticular muscle trauma following THA depending on the approach (12). In the lateral DL the anterior part of the GMM showed more fatty atrophy and a compensatory hypertrophy of the TFLM was observed. In patients who received an ALMI, the atrophy was less. It is important to note that the muscle trauma in the lateral approach is related to a direct muscle split, whereas in the ALMI the muscle is primarily stretched and crushed. Our current findings, increased fiber diameter and fiber type shift in the TFLM, prove the observed muscle hypertrophy (increase in muscle fiber size) on a microstructural level. As described above, compensatory increase in size of the TFLM was observed on the MRI before (12). This total increase in muscle volume due to muscle hypertrophy is well described in sports literature from exercise induced muscle damage. (reviewed in (18)). However, muscle hyperplasia (increase in total amount of muscle fibers) as a result of trauma, remains controversially discussed in the literature. Various authors have proposed three possibilities underlying muscle hyperplasia:

- (i) entirely new fibers are formed in the interstitial connective tissue;
- (ii) newly formed myofibers arise from host satellite cell fusion with native myofibers;
- (iii) or damaged myofibers forming new "branched" myofibers with host satellite cells (9, 10, 14).

Unfortunately, our data does not allow a quantitative analysis on possible muscle hyperplasia following THA.

Our results show that the effect of muscle trauma is larger on the TFLM than on the GMM, in both surgical approaches. The largest post-operative changes in fiber diameter and muscle composition were seen in the DL. The hypertrophy of the TFLM, as described above, may be due to a taking over of biomechanical functions of the traumatized GMM. Both muscles, GMM and TFLM, respectively, are synergistically responsible for abduction of the hip and stabilization of the hip joint during walking. If the one muscle is intra-operatively traumatized, the other has to compensate the reduced function. Our data suggest that in both operations the GMM is injured, however the trauma towards to GMM is greater in the DL, and therefore the compensatory effect is more pro-

nounced. Especially during the DL the anterior part of the GMM is detached, which is primarily important for internal rotation of the hip. It is known that the posterolateral fibers of the TFLM possess the ability for internal rotation (15). Most likely, these postolateral fibers are compensating the lack of internal rotation following operative trauma towards the GMM.

In literature the ALMI has been shown to yield better functional results when compared to the DL. Our data support these findings, since compensatory mechanisms of the musculature were less pronounced in the ALMI. These findings may support the advantages of the ALMI in the early post-operative phase.

Despite the novel findings of this study, there are certain limitations and the data interpretation has to be accordingly: Due to non-randomization of patients a certain bias could have been introduced in this study. For example, it has recently been shown that patient age should be a deciding factor in decisions of surgical approaches in THA. Elderly patients had a significantly better functional outcome when operated by a minimally invasive approach (11). Furthermore, all patients were operated by three attending surgeons and the total number of patients is relatively small. Therefore, our results have to be confirmed by other investigators and preferably in larger cohorts.

CONCLUSIONS

In comparison to the DL, even when used in a modified technique, the ALMI seems to be favorable in respect to macrostructural and microstructural damage as could be shown by our results. Our data adds to the existing literature supporting the use of the ALMI for standard THA.

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