International Orthopaedics (SICOT) (2011) 35:165–171
DOI 10.1007/s00264-010-1166-6

ORIGINAL PAPER

Age-related appearance of muscle trauma in primary total hip arthroplasty and the benefit of a minimally invasive approach for patients older than 70 years

Michael Müller · Stephan Tohtz · Marc Dewey · Ivonne Springer · Carsten Perka

Received: 17 October 2010 / Revised: 3 November 2010 / Accepted: 3 November 2010 / Published online: 2 December 2010

Abstract Old age is frequently associated with a poorer functional outcome after THA. This might be based upon muscular damage resulting from surgical trauma. Minimally invasive approaches have been widely promoted on the basis of the muscle sparing effect. The aim of the study was to evaluate of the functional outcome and the grade of fatty muscle atrophy of the gluteus medius muscle by magnetic-resonance-imaging (MRI) in patients undergoing minimally invasive or traditional THA. Forty patients (21 female, 19 male) underwent THA either via a modified direct lateral (mDL) or a minimally invasive anterolateral (ALMI) approach. Patients were evaluated clinically and by MRI in terms of age (< or ≥70 y) preoperatively and at three and 12 months postoperatively. The Harris hip score and Trendelenburg's sign were recorded and a survey of a pain (using a numeric rating scale of 0–10) and satisfaction score (using a numeric rating scale of 1–6) was performed. Fatty atrophy (FA) of gluteus medius muscle was rated by means of a five-point rating scale (0 indicates no fat and 4 implies more fat than muscle). Younger patients reached a significantly higher Harris hip score, lower pain score and lower rate of positive Trendelenburg's sign accompanied by a significantly lower rate of postoperative FA (P=0.03; young: FA (MW)=(preop. / 3 / 12 months), 0.15 / 0.7 / 0.7; old: FA (MW)=0.18 / 1.3 / 1.36). Older patients with an mDL-approach had the significantly lowest clinical scores, the highest rate of positive Trendelenburg's sign and also the highest rate of fatty atrophy (P=0.03; FA (old) mDL: 1.8; ALMI: 0.7). Interestingly, no influence of the approach could be detected within the younger group. Patients older than 70 years had a poorer functional outcome and a higher postoperative extent of FA when compared to younger patients, which must be based upon a higher vulnerability and a reduced regenerative capacity of their skeletal muscle. Through a minimally invasive approach the muscle trauma in older patients can be effectively reduced and thus the functional outcome significantly improved. Incision and detachment of tendons and muscles should be strictly avoided.

S. Tohtz · C. Perka
Department of Orthopaedics,
Charité – University Medicine Berlin,
Berlin, Germany

M. Dewey · I. Springer
Department of Radiology, Charité – University Medicine Berlin,
Berlin, Germany

M. Müller (✉)
Centre for Musculoskeletal Surgery, Department of Orthopaedics,
Charité - University Medicine Berlin,
Charitéplatz 1,
10117, Berlin, Germany
e-mail: michael.mueller@charite.de

Introduction

Several studies have demonstrated the association between higher age and a lower functional outcome after primary total hip arthroplasty (THA) [1–3]. A reduced walking distance, a prolonged dependence on walking aids and a significantly more frequent incidence of dislocation were much more prevalent among older patients [1, 2]. One crucial parameter, essential for an adequate functional outcome after THA, is the preservation of muscular integrity. Impairment of muscular integrity leads to weakened muscle and poorer function. Hence, it might be postulated that older patients possess a higher muscular vulnerability and, therefore, may expect a poorer functional outcome after THA.

In recent years, minimally invasive THA has been established to reduce muscular trauma and optimise functional outcome [4–8]. For this reason, older patients should benefit from a minimally invasive muscle sparing approach and present a better outcome after THA.

Structural changes in skeletal muscles after THA can be displayed and analysed by means of magnetic resonance imaging [9–11]. Fatty muscle atrophy is one structural property which results from severe muscle trauma and clearly correlates to the muscle function [9, 12].

By taking these considerations into account, the following questions arose: (1) Is there a higher extent of fatty muscle atrophy on MR scanning in the elderly (>70 years) compared to younger patients undergoing THA?, (2) Is there a correlation between the functional outcome and the MRI-findings? and (3) Is it possible to reduce muscle trauma in older patients via a minimally invasive approach and would they therefore particularly benefit from such a minimally invasive approach?

Material and methods

Forty patients (21 female, 19 male) undergoing primary total hip arthroplasty for primary coxarthrosis were enrolled in this study. Average age was 65 years (range 35–80) and the mean body mass index was 27.6 kg/m^2 (19.7–37.5). Exclusion criteria were higher grade of dysplasia (≥Crowe Type II), fractures, necessity for osteotomies, previous hip surgery, rheumatoid arthritis, or any mental or physical disabilities. Written informed consent was obtained from all patients. The study was approved by the institutional review board (EA 1/068/06). THA was performed either through a minimally invasive anterolateral approach (ALMI, n=22) or via a modified direct lateral approach (mDL, n=18). All operations were carried out by two surgeons (S.T. und C.P.) who each have performed more than 1,500 arthroplasties via the applied approaches.

The ALMI-approach uses the intermuscular plane between the tensor fascia latae and the gluteus medius muscle [5]. Any incision or detachment of muscles and tendons is avoided. However, musculature might be bluntly damaged during the acetabular and femoral preparation due to retractor compression.

The modified direct lateral approach is a modified form of the approach which was initially described by Hardinge [13]. In the modified form the gluteus medius is incised to a maximum length of 3 cm and detached together with the gluteus minimus ventrally from the greater trochanter [4]. Prolonging incision into the vastus lateralis is strictly avoided. Gluteal tendons are reattached with strong trans-periosteal sutures.

A tapered uncemented straight titanium stem (Zweymüller®, Smith and Nephew®, Rotkreuz, Switzerland) and a uncemented press-fit cup (Allofit®, Zimmer®, Warsaw, Indiana, USA) were used.

Patients were clinically evaluated clinically and by MRI scan preoperatively and at three and 12 months postoperatively. The Harris hip scores were recorded and a survey of a pain (using a numeric rating scale of 0–10) and satisfaction score (using a numeric rating scale of 1–6) was performed. Additionally, the Trendelenburg's signs were evaluated to assess the abductor muscle strength. The Trendelenburg's sign was rated as either negative, slightly positive (wobbly, unstable standing on one leg, but without limping) or severely positive (unable to stand on one leg, limping). Clinical analysis was carried out by the same single observer (M.M.). All patients experienced the same postoperative care and rehabilitation. Crutches were used for at least six weeks.

All MRI scans were performed on a 1.5 T MR-system (Symphony; Siemens Medical Solutions, Erlangen, Germany).

The fatty atrophy (FA) of the gluteus medius muscle was assessed on the transverse T1-weighted MR images at the lower one-third of the distance between the iliac crest and the tip of the greater trochanter. The anterior, middle and posterior third of the gluteus medius were evaluated separately and the mean value was computed. The grading system used has already been described for the evaluation of gluteus muscle [9, 11] and corresponds to a classification system that is commonly used to categorise the rotator cuff muscles [14]. Grade 0 means no fat was visible; grade 1: some fatty streaks were present; grade 2: fat was evident, but there was less fat than muscle tissue; grade 3 implies that there were equal amounts of fat and muscle tissue; and grade 4 that there was more fat than muscle tissue. The MRI images were evaluated independently by two radiologists (M.D. and I.S.) who were blinded to the study group and the surgical approach. The kappa statistic was used to assess interobserver agreement.

According to the age (< or ≥70) and the surgical approach (mDL/ALMI), the clinical and radiological data were separately evaluated. In total, 24 patients were younger and 16

Table 1 Demographic data

Demographic	Age<70	Age≥70	*P*
Number of patients	24	16	
Age	58±10	74±4	>0.01
BMI	27±4	27±3	1
Gender (female/male)	13 / 11	8 / 8	0.94
Approach (mDL/ALMI)	11 / 13	7 / 9	0.74

BMI body mass index, *mDL* modified direct lateral approach, *ALMI* minimally invasive anterolateral approach

Table 2 Clinical scores (HHS, pain, satisfaction) and Trendelenburg's sign at each follow-up time point for patients younger and older than 70 years of age

Clinical measurement	Age<70 (n=24)	Age≥70 (n = 16)	P
Harris hip score (HHS)			
Preoperatively	54±7	54±8	1[a]
Three months	84±13	73±16	0.04[a]
12 months	92±10	81±12	0.02[a]
Satisfaction score (1–6)			
Three months	1.8±0.8	2.4±1.3	0.11[a]
12 months	1.7±0.9	2.3±1.7	0.2[a]
Pain score (VAS 0–10)			
Three months	1.7±1.0	2.5±1.6	0.08[a]
12 months	1.8±1.3	2.9±1.8	0.04[a]
Trendelenburg's sign			
Preoperatively			
No	20	13	0.79[b]
Mild	4	3	
Severe			
Three months			
No	20	9	0.09[b]
Mild	1	4	
Severe	3	1	
12 months			
No	20	11	0.7[b]
Mild	4	3	
Severe			

[a] *t*-test

[b] Chi-square test

patients older than 70 years. The average age of the younger group was 58 years and 74 years was that of the older group. Significant differences in BMI (young: 27 kg/m^2; old: 27.4 kg/m^2), gender (young: 13 female, 11 male; old: eight female, eight male), and surgical approach (young: 11 mDL, 13 ALMI; old: nine mDL, seven ALMI) were not evident between the two patient groups (Table 1).

Statistical analysis was performed with the statistical software SPSS (Version 15, SPSS Inc., Chicago, USA). Pre- and postoperative normally (continuous) distributed variables were calculated using the Student's *t*-test. Non-normally distributed data were compared using a Mann-Whitney U Test. For nominal variables the chi-square test was applied. The kappa-statistic was used to calculate intra-observer agreement. A *p*-value of less than 0.05 was considered significant.

Results

The results demonstrate a significant impact of the age on the clinical outcome and the grade of fatty muscle atrophy.

Patients younger than 70 years reached a significantly higher Harris hip score and a significantly lower pain

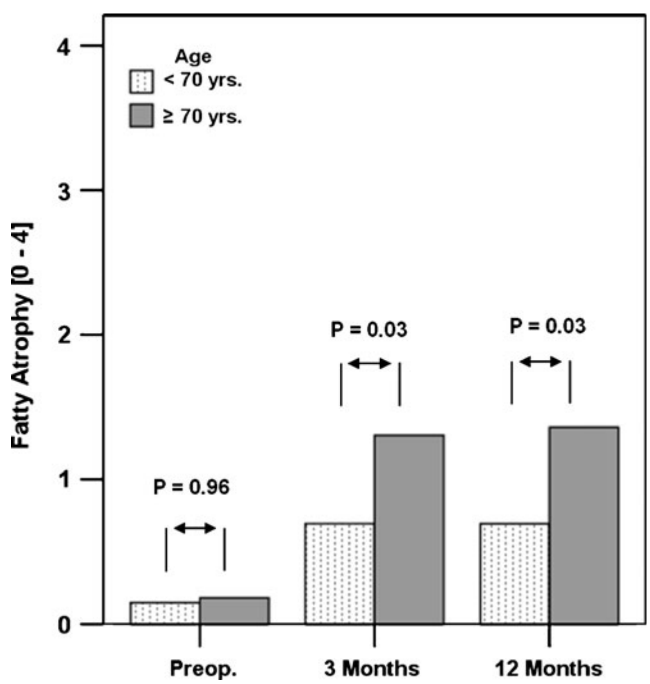

Fig. 1 Graphical depiction of the mean fatty atrophy in younger (<70, average age 58 y) and older (≥70, average age 74 y) patients group preoperatively, at three months and at 12 months. A significantly higher rate of muscle atrophy is represented in the older patient group postoperatively (P=0.03; Mann-Whitney U test)

score compared to the older group. In addition, after three months the rate of positive Trendelenburg's sign was significantly higher in patients over 70 years of age (Table 2).

Compared to younger patients, a significantly higher rate of fatty atrophy of the gluteus medius muscle occurred in the older patient group at three and at 12 months postoperatively. (P=0.03; Mann-Whitney U test) (young: FA (MW)=(preop. / 3 / 12 months); 0.15 / 0.7 / 0.7; old: FA (MW)=0.18 / 1.3 / 1.36). No difference in grade of fatty muscle atrophy was evident preoperatively (Fig. 1). The intra-observer agreement was moderate to excellent (0.51–0.89).

Figure 2 exemplifies pre- and postoperative axial T1-weighted TSE images on height of the acetabulum for a patient younger and one older than 70 years.

With respect to the surgical approach, a clear impact of the approach on functional outcome and fatty muscle atrophy could be demonstrated in the older patient group. In contrast, the functional outcome in the younger patient group was not affected by the approach. Older patients, who underwent THA through a minimally invasive approach, gained significantly better clinical scores, less pain, and a lower rate of positive Trendelenburg's sign postoperatively in comparison to those with an mDL approach (Table 3). This significant impact of the surgical approach on clinical scores was not evident within the younger patient group.

Corresponding to the clinical outcome parameter, the highest rate of fatty muscle atrophy was also evident in the older patient group with an mDL approach (mean, 1.8). In comparison, older patients with an ALMI-approach had significantly less FA (mean, 0.7; P=0.033; MWU). Within the younger patient group the mean FA was 0.5 (ALMI) and 0.7 (mDL), respectively, without significant difference (P=0.803; MWU). In addition, the grade of FA between older and younger patients with an mDL approach was also significant (P=0.024, MWU). Figure 3 represents the mean FA values for older and younger patients with regard to the applied approach.

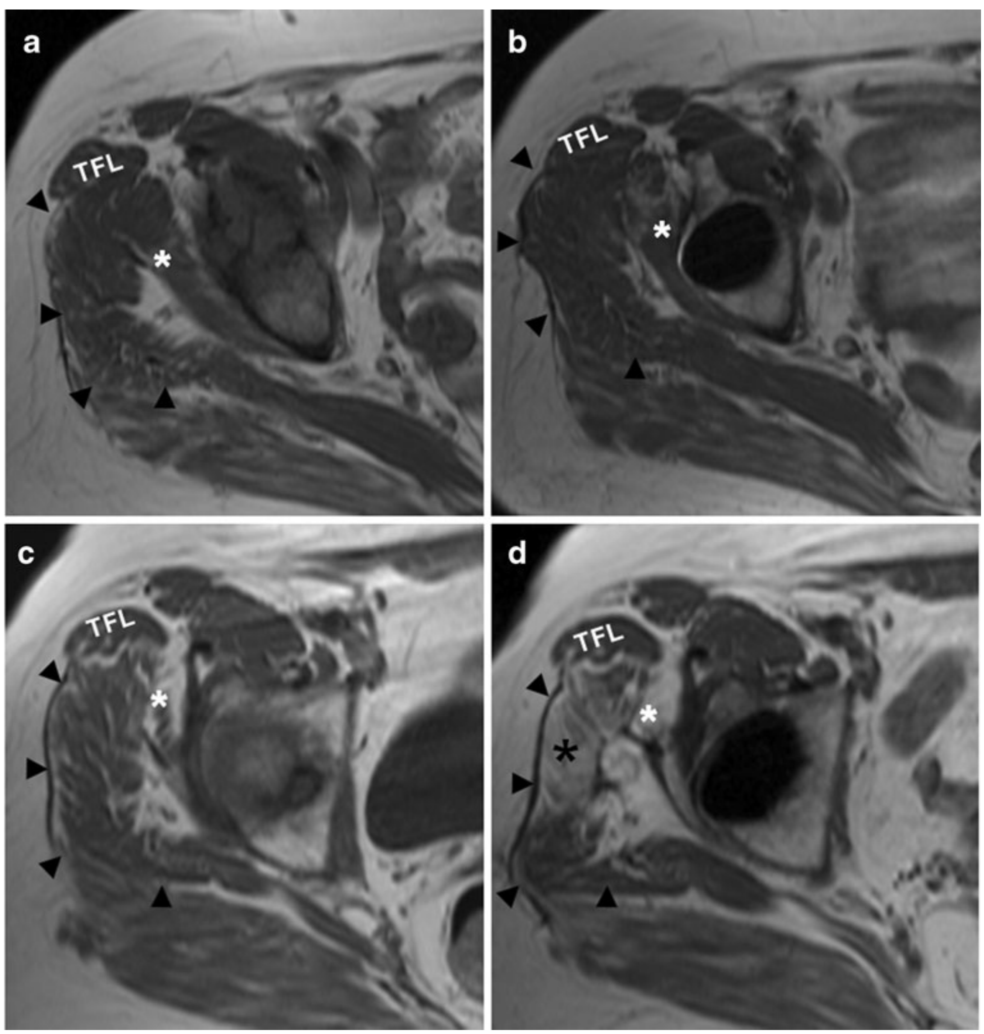

Fig. 2 Pre- (**a**, **c**) and postoperative (**b**, **d**) axial T1 weighted TSE MR-images on height of the acetabulum. Patient 1 (**a**, **b**) (55 years, ALMI approach) had no postoperative fatty atrophy of the gluteus medius muscle (*black arrowheads*). Patient 2 (**c**, **d**) (73 years, mDL approach) had a clear postoperative fatty atrophy of the anterior part of the gluteus medius muscle (**b**: grade 4; *black asterisks*). *Black arrowheads* indicate gluteus medius muscle, *black asterisks* show grade 4 atrophy of the anterior part of the gluteus medius muscle, *white asterisks* are the gluteus minimus muscle, and *TFL* is the tensor fascia latae muscle

Table 3 Clinical scores (HHS, pain, satisfaction) and Trendelenburg's sign at each follow-up time point for patients younger and older than 70 years of age and the respective approach

Clinical measurement	Age<70		*P*	Age≥70		*P*
	ALMI (*n* = 13)	mDL (*n* = 11)		ALMI (*n* = 7)	mDL (*n* = 9)	
Harris hip score						
Three months	87±9	84±12	0.5	83±5	66±14	>0.01[a]
12 months	92±8	89±10	0.43	85±8	73±13	0.03[a]
Pain score (0–10)						
Three months	1.7±1.1	1.8±2.6	0.9	1.2±0.7	3.5±2.7	0.02[a]
12 months	1.7±1.2	1.6±1.8	0.87	1.6±1.1	3.4±2.1	0.05[a]
Satisfaction score (1–6)						
Three months	1.8±0.7	1.9±0.9	0.77	1.6±0.5	3±1.5	0.02[a]
12 months	1.6±0.8	1.8±0.9	0.57	1.5±0.6	2.8±2	0.09[a]
Trendelenburg's sign						
Three months						
No	12	8	0.19	6	5	0.19[b]
Mild		1		1	3	
Severe	1	2			1	
12 months						
No	12	8	0.19	7	6	0.09[b]
Mild	1	2			3	
Severe		1				

mDL modified direct lateral approach, *ALMI* minimally invasive anterolateral approach

[a] *t*-test

[b] chi-square

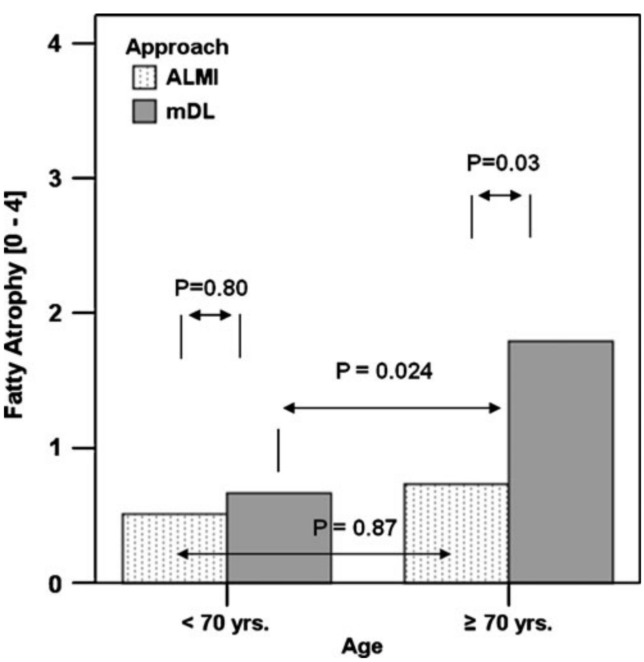

Fig. 3 Mean fatty atrophy of the gluteus medius muscle for patients <70 and ≥70 years at three months postoperatively in relation to the surgical approach (modified direct lateral approach/minimally invasive anterolateral approach). The highest FA was seen in older patients who underwent THA through a modified direct lateral approach (*P*=0.033)

Discussion

The results of this study demonstrate the significant impact of age on the clinical outcome and on the postoperative extent of fatty muscle atrophy. In addition, the surgical approach had a clear influence on the functional and MR tomographic outcome in older patients. The age-related impact on clinical outcome after THA has been already observed by several authors but without giving any explanation [2, 3, 15]. The rationale for the poorer functional outcome after THA in elderly seems to be substantiated by muscular changes in the form of a higher incidence of postoperative fatty muscle atrophy which obviously correlates with the reduced muscular function. To our knowledge, this age-related effect on muscle atrophy in patients undergoing THA has not been described clinically previously. Apparently, skeletal musculature of elderly patients possesses a higher vulnerability and a reduced regenerative capacity. This might be also the reason for the clear impact of the surgical approach on fatty muscle atrophy. Older patients who underwent THA through the more invasive mDL approach had a significantly higher grade of muscle atrophy than older patients with a minimally invasive approach in which incision and detachment of musculature and tendons had been avoided. In contrast, this approach-dependent effect was not evident in the younger patient group which obviously possesses a sufficient regenerative capacity. Our results reflect the results of experimental studies and could be explained on a pathophysiological basis. Experimental studies demonstrate that higher age is associated with a generally reduced regenerative capacity [16–20]. This age-associated reduced regenerative capacity is accompanied by a reduced muscle mass [20], an increased vulnerability [16] and a prolonged regeneration time [19]. The cause of the reduced regenerative capacity is based on molecular biological changes. The onset of muscle regeneration after injury or overloading is the activation and proliferation of skeletal muscle satellite cells which are located in the resting state under the basal lamina of the muscle fibre [21]. After trauma, the satellite cells exit their resting state and start to proliferate into myoblasts and these myoblasts fuse and form to existing muscle fibrils and new muscle fibrils [21]. Now, it has been shown that there is a significant decline of satellite cells in humans older than 70 years [22] and that these satellite cells have a reduced proliferative capacity [23]. Furthermore, satellite cells of elderly humans should have an increased rate of apoptosis, especially in a pro-apoptotic cellular environment such as injured muscle tissue [18]. In addition, elderly skeletal muscle tissue possesses a reduced (micro) vascular density with a corresponding reduced level of VGEF'S and –mRNA [24, 25]. All these facts together constitute the supposed reduced regenerative capacity and increased vulnerability of the skeletal muscle in elderly patients, which lead to the increased fatty muscle degeneration as demonstrated in this study.

It seems that the musculature of younger patients is able to compensate better following a more invasive surgical approach and hence, differences to a MIS-approach do not become evident MR-tomographically. In contrast, clear structural differences are noticeable in elderly patients who clearly benefit from a minimally invasive approach.

From our point of view, these findings are of current interest because the application of a minimally invasive THA is frequently recommended for younger patients who belong to the workforce and need an excellent muscular outcome [6, 26]. But obviously, these patients are not as sensitive to muscular trauma and they possess sufficient regenerative capacity. This would also explain that a number of comparative studies were not able to find any significant difference in the clinical outcome between patients who underwent THA through a minimally invasive or a traditional approach [7, 8, 27–30]. The controversial discussion about the advantage of minimally invasive THA which has arisen in recent years, therefore gains a new aspect. In brief, minimally invasive THA truly reduces muscle trauma and improves functional outcome, but more so in elderly patients.

In conclusion, elderly (>70 years) have a higher grade of postoperative fatty gluteus medius muscle atrophy than younger patients after THA. This seems to be the most likely reason for the concomitant appearance of a poorer functional outcome which clearly relates to the extent of fatty muscle atrophy. In comparison to younger patients a clear impact of the surgical approach was also evident in older patients who definitely benefit from a minimally invasive approach. Clearly, older patients have a reduced regenerative capacity and a higher vulnerability of their skeletal musculature. Therefore, especially in elderly patients a minimally invasive approach should be applied and any incision and detachment of tendons and muscles should be strictly avoided.

Conflict of interest statement The authors have no conflict of interest to report. No specific funding was received.

References

1. Ogino D, Kawaji H, Konttinen L, Lehto M, Rantanen P, Malmivaara A, Konttinen YT, Salo J (2008) Total hip replacement in patients eighty years of age and older. J Bone Jt Surg 90 (9):1884–1890
2. Pettine KA, Aamlid BC, Cabanela ME (1991) Elective total hip arthroplasty in patients older than 80 years of age. Clin Orthop Relat Res 266:127–132
3. Roder C, Parvizi J, Eggli S, Berry DJ, Muller ME, Busato A (2003) Demographic factors affecting long-term outcome of total hip arthroplasty. Clin Orthop Relat Res 417:62–73
4. O'Brien DA, Rorabeck CH (2005) The mini-incision direct lateral approach in primary total hip arthroplasty. Clin Orthop Relat Res 441:99–103
5. Bertin KC, Rottinger H (2004) Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. Clin Orthop Relat Res 429:248–255
6. Malik A, Dorr LD (2007) The science of minimally invasive total hip arthroplasty. Clin Orthop Relat Res 463:74–84
7. Cheng T, Feng JG, Liu T, Zhang XL (2009) Minimally invasive total hip arthroplasty: a systematic review. Int Orthop 33(6):1473–1481
8. Smith TO, Blake V, Hing CB (2010) Minimally invasive versus conventional exposure for total hip arthroplasty: a systematic review and meta-analysis of clinical and radiological outcomes. Int Orthop. doi:10.1007/s00264-010-1075-8
9. Pfirrmann CW, Notzli HP, Dora C, Hodler J, Zanetti M (2005) Abductor tendons and muscles assessed at MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology 235(3):969–976
10. Muller M, Tohtz S, Dewey M, Springer I, Perka C (2010) Evidence of reduced muscle trauma through a minimally invasive anterolateral approach by means of MRI. Clin Orthop Relat Res. doi:10.1007/s11999-010-1378-5

11. Muller M, Tohtz S, Winkler T, Dewey M, Springer I, Perka C (2010) MRI findings of gluteus minimus muscle damage in primary total hip arthroplasty and the influence on clinical outcome. Arch Orthop Trauma Surg. doi:10.1007/s00402-010-1085-4
12. Gladstone J, Bishop J, Lo I, Flatow E (2007) Fatty infiltration and atrophy of the rotator cuff do not improve after rotator cuff repair and correlate with poor functional outcome. Am J Sports Med 35 (5):719–728
13. Hardinge K (1982) The direct lateral approach to the hip. J Bone Joint Surg Br 64(1):17–19
14. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC (1994) Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res 304:78–83
15. Johnsson R, Thorngren KG (1989) Function after total hip replacement for primary osteoarthritis. Int Orthop 13(4):221–225
16. Brooks SV, Faulkner JA (1988) Contractile properties of skeletal muscles from young, adult and aged mice. J Physiol 404:71–82
17. Jarvinen M, Aho AJ, Lehto M, Toivonen H (1983) Age dependent repair of muscle rupture. A histological and microangiographical study in rats. Acta Orthop Scand 54(1):64–74
18. Jejurikar SS, Henkelman EA, Cederna PS, Marcelo CL, Urbanchek MG, Kuzon WM Jr (2006) Aging increases the susceptibility of skeletal muscle derived satellite cells to apoptosis. Exp Gerontol 41 (9):828–836
19. McBride TA, Gorin FA, Carlsen RC (1995) Prolonged recovery and reduced adaptation in aged rat muscle following eccentric exercise. Mech Ageing Dev 83(3):185–200
20. Tinetti ME (1987) Factors associated with serious injury during falls by ambulatory nursing home residents. J Am Geriatr Soc 35 (7):644–648
21. Hill M, Wernig A, Goldspink G (2003) Muscle satellite (stem) cell activation during local tissue injury and repair. J Anat 203(1): 89–99
22. Kadi F, Charifi N, Denis C, Lexell J (2004) Satellite cells and myonuclei in young and elderly women and men. Muscle Nerve 29(1):120–127
23. Schultz E, Lipton BH (1982) Skeletal muscle satellite cells: changes in proliferation potential as a function of age. Mech Ageing Dev 20(4):377–383
24. Croley AN, Zwetsloot KA, Westerkamp LM, Ryan NA, Pendergast AM, Hickner RC, Pofahl WE, Gavin TP (2005) Lower capillarization, VEGF protein, and VEGF mRNA response to acute exercise in the vastus lateralis muscle of aged vs. young women. J Appl Physiol 99(5):1872–1879
25. Parizkova J, Eiselt E, Sprynarova S, Wachtlova M (1971) Body composition, aerobic capacity, and density of muscle capillaries in young and old men. J Appl Physiol 31(3):323–325
26. Howell JR, Garbuz DS, Duncan CP (2004) Minimally invasive hip replacement: rationale, applied anatomy, and instrumentation. Orthop Clin North Am 35(2):107–118
27. Ogonda L, Wilson R, Archbold P, Lawlor M, Humphreys P, O'Brien S, Beverland D (2005) A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes. A prospective, randomized, controlled trial. J Bone Jt Surg 87(4):701–710
28. Peck CN, Foster A, McLauchlan GJ (2006) Reducing incision length or intensifying rehabilitation: what makes the difference to length of stay in total hip replacement in a UK setting? Int Orthop 30(5):395–398
29. Pospischill M, Kranzl A, Attwenger B, Knahr K (2010) Minimally invasive compared with traditional transgluteal approach for total hip arthroplasty: a comparative gait analysis. J Bone Jt Surg 92(2):328–337
30. Woolson ST, Mow CS, Syquia JF, Lannin JV, Schurman DJ (2004) Comparison of primary total hip replacements performed with a standard incision or a mini-incision. J Bone Jt Surg 86-A (7):1353–1358