Hip abductor dysfunction following total hip arthroplasty by modified direct lateral approach: assessment by quantitative electromyography

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Received: 14 August 2023
Revised: 24 September 2023
Accepted: 07 October 2023
Published: 27 January 2024

The Egyptian Orthopaedic Journal 2023, 58:295–304

Background
The use of the direct lateral approach and its modifications for total hip arthroplasty (THA) may lead to postoperative abductor weakness. Assessment of abductor muscle function by the use of quantitative electromyography (EMG) aims to investigate the nature of abductor muscle dysfunction.

Methods
We conducted a study on 40 patients who had hip replacement through the modified direct lateral approach. EMG was performed before surgery on the affected and normal sides and repeated on the operated side after surgery by 6 and 12 weeks. Analysis of EMG of the three abductor muscles was done in all patients.

Results
EMG evidence of acute denervation of hip abductors was present in 15 hips (37.5%) after 6 weeks. Improvement of EMG findings occurred in 8 out of 15 patients. Quantitative electromyography (QEMG) showed early significant increase in amplitude in all muscles and decrease in duration in gluteus medius (G. Med) with a pattern of acute nerve injury. At 12 weeks, the values of duration, amplitude, and phase were insignificantly different from the preoperative values signifying the return of near normal muscle activity.

Conclusion
The use of modified direct lateral approach can cause denervation of hip abductors. It is common in the early postoperative weeks. However, it tends to improve and the residual weakness in some patients is not marked. Quantitative electromyography showed that partial denervation is related to superior gluteal nerve stretching and not to direct injury of the terminal branches of the nerve through the incision.

Keywords:
hip arthroplasty, lateral approach hip, quantitative electromyography

Egypt Orthop J 2023, 58:295–304

1110-1148

Introduction

The main concern in performing lateral approaches of the hip for joint replacement is abductor muscle dysfunction [1,2]. The transgluteal approach [3] and the direct lateral approach [4] or their modifications [1,5–8] entail partial incision through the gluteus medius (G. Med) muscle and detachment of the insertion of both the G Med and minimus off the greater trochanter. Proximal incision through the fibers of G Med can endanger the superior gluteal nerve (SGN) whose ramifications or the inferior trunk are close with a variable distance from the apex of the trochanter. This 'safe zone' has been thoroughly studied [9–13] or even questioned by many authors [14–17]. In spite of recommendations of all surgical approaches that proximal extension should not exceed 2–5 cms from the tip of the greater trochanter [1,3,7,8,10,18–20] or 2–4 cms from superior lateral acetabular rim [6,21], still there are reports of SGN injury as proved by electromyography (EMG) [2,22–26], or observed in clinical studies [24,27–31]. Abductor weakness leads to increased stresses around the acetabular components [32], and can affect long-term survival of the implant. The incidence of postoperative abductor muscles denervation as reported by EMG ranges from 3.4 to 56% [2,22–25]. Abductor muscle dysfunction has been also explained as a result of muscle damage or inappropriate repair [2,23,25,33].

Routine EMG studies are based on subjective, ordinal data representing the motor unit action potential

(MUAP) electrical activity expressed in qualitative terms and it is very dependent on the examiner experience [34]. Quantitative electromyography (QEMG) has the benefit of reducing examiner bias in data collection and providing numerical values that can be followed and compared over time and it's more objective [34,35]. It can help to recognize mild abnormalities if the muscle is minimally affected and in early neurogenic process where EMG findings on subjective assessment may be equivocal [36,37]. The aim of this work is to evaluate abductor muscle function by QEMG after modified direct lateral approach for hip replacement. QEMG analysis will be used to explain the possible causes of abductor dysfunction.

Patients and methods

This is a prospective case series study in which 40 patients who had been operated on by THA for the diagnosis of advanced hip arthritis (OA) or fracture neck of femur (FNF) with normal contralateral hip were included.

Any patient above the age of 18 years old that is undergoing THA for either OA or FNF in the period between April 2018 and April 2019 were included in our study. Patients with previous neurological diseases, patients with poor diabetic control (HbA1c more than 6), peripheral neuropathies, Epilepsy, and patients with previous hip surgery were excluded.

For all patients, the procedure was explained and a written consent for the surgery and participation in the study was obtained and the standard preoperative clinical and laboratory assessment were done.

Clinical examination of the hip was done in OA patients including testing of abductor muscle power by Medical Research Council (MRC) grading of muscle power [38]. This method involves testing the abductors against the examiner's resistance and grading the patient's strength on a 0–5 scale accordingly. Trendelenberg test was done as modified by Hardcastle and Nade [39].

For patients who had FNF we could not assess them clinically preoperatively. So we evaluated them clinically and recorded Trendelenburg test results and MRC grading postoperative after twelve weeks. The study was approved by the Ethical Committee in our Institution (IRB NO. 17100496). The primary outcome of this study is to analyze the percentage of patients having abnormal EMG after THA using the lateral approach and how many patients of them are due to direct denervation.

Surgical procedure

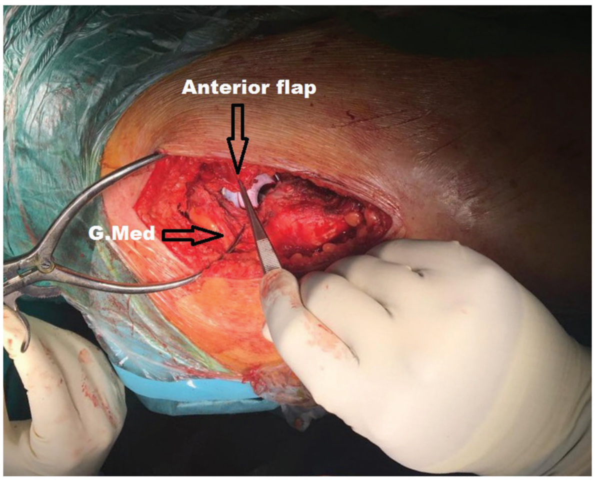
A modified direct lateral approach [1,5–8] with the patient in lateral position had been used in all cases. The split in the fibers of G Med is made more anteriorly than the transgluteal [3] approach or the classic direct lateral [4] approach in the anterior third of the muscle mass and continues to preserve the tendinous continuity distally with the vastus lateralis (Fig. 1). The split is limited proximally to less than 3 cm above greater trochanter to prevent injury to SGN. Anterior flap is developed and anterior joint capsule is exposed to be closed later on before repair of gluteus medius. The capsule is closed with heavy sutures typically through holes in the trochanter to reattach the anterior flap to the intertrochanteric region, then the G Med tendon proximally and vastus lateralis distally are closed. All surgeries were performed by three experienced surgeons who had at least 10 years of experience in performing the modified Harding approach. Postoperatively all patients received the same rehabilitation program with hip muscle static strengthening exercises.

Quantitative EMG

QEMG of the three muscles supplied by SGN i.e. G.Med, gluteus minimus (G.Min) and tensor fascia lata (TFL) was done on the side of the operation and the other side as a control before surgery and repeated on the operated side 6 weeks and 12 weeks postoperative.

The EMG was recorded with the ordinary concentric needle electrode from the three muscles. A more complete assessment the muscle which usually requires 2 to 4 different passes through the muscle moving along a straight line through the muscle in short steps

Figure 1



The anterior muscle flap in gluteus medius (G.Med) muscle elevated to show the proximal extension of the muscle incision.

Figure 2

Needle electromyography examination of hip abductors after surgery with the patient on his side and the examiner testing the gluteus minimus muscle.

(0.5–1 mm) [40,41], guided by the surface landmarks ASIS, PSIS and Greater Trochanter. (Fig. 2).

EMG device: Neuropack S1 MEB-9400 (Nihon Kodhen) with QP-951 Quantitative EMG Software.

The following examinations were done.

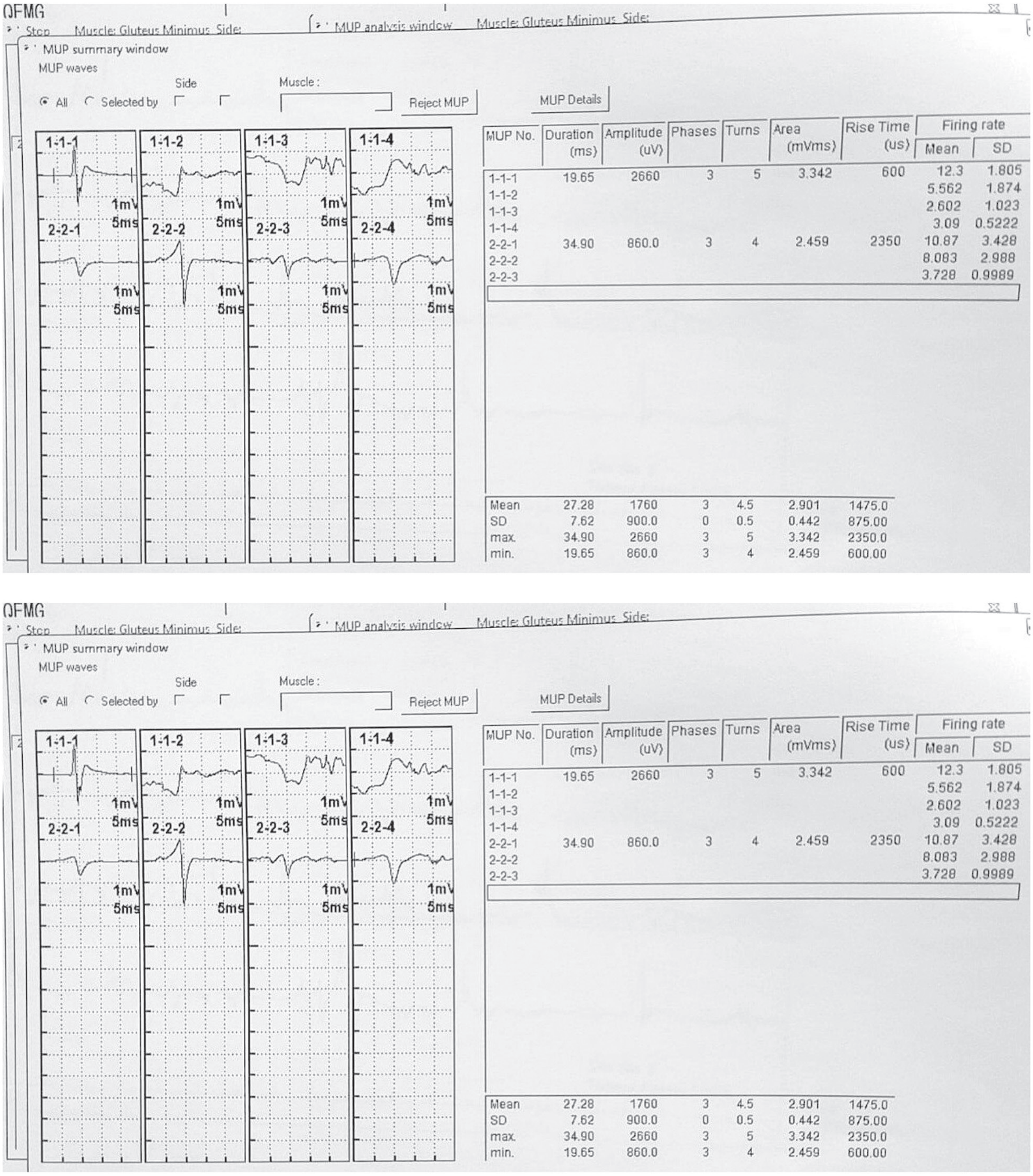
Examining a resting muscle

For detection of abnormal spontaneous discharges (positive sharp waves or fibrillation potentials) that may be indicators of denervation. Normally there is no spontaneous activity at rest.

Examining a contracting muscle

With gentle active hip abduction, the morphologic features (amplitude, duration, and phases) of the MUAP are recorded. Measurement of MUAPs and analysis of interference patterns are typically made by QEMG to measure MUAP parameters and isolating and recording MUAPs in different areas of the muscle (Fig. 3a and b). This was only done for all patients except patients with FNFS.

Figure 3



Quantitative electromyography analysis of gluteus minimus muscle. A-MUP analysis window of 4 motor units. B- Analysis of amplitude, duration and phase.

Analysis of the MUAPs

The parameters are automatically calculated by software for MUAP analysis. Acute or ongoing denervation is diagnosed by abnormal rest potentials and MUAPs that may have abnormal parameters, or vary in morphology from the base line preoperative QEMG.

A further follow-up QEMG was undertaken 3 months (mean 95 days) postoperative. Signs of re-innervation were determined by normalization of the morphology, amplitude, duration and firing pattern of the MUAP.

Statistical analysis

We used the SPSS (v. 12.0.; IBM Corporation, Somers, NY USA) to test the difference between averaged measurements using parametric (one sample mean test, and independent samples *t*-test), and nonparametric (Mann–Whitney-*U* test) statistical tests.

The sample size for this case series study were calculated as the total coverage of patients undergoing THA in the period from April2018 to April 2019 who met our inclusion criteria.

Results

Mean age of the enrolled patients was 56.35 ± 12.9 years with a range between 23 and 85 years. Out of those patients; 23 (57.5%) patients were males and 17 (42.5%) patients were females. OA and FNF were present in 22 (55%) and 18 (45%) patients, respectively.

Pre-operative QEMG analysis

Preoperatively, all patients had normal EMG of G.Med, G min and TFL. There were no significant differences between baseline QEMG parameters of all three muscles in the side to be operated on (affected) and the contralateral (normal) side (Table 1).

Postoperative QEMG analysis

(1) Follow-up electrophysiological study results after 6 and 12 weeks.

In the first follow-up after 6 weeks postoperative, 25 patients has normal EMG while 15 (37.5%) patients showed EMG evidence of acute denervation of hip abductors in the form of positive sharp waves or fibrillation potentials (abnormal rest potentials) with abnormal MUAP parameters.

After 12 weeks, improvement of EMG findings occurred in 8 out of 15 patients with the total number of 33 out of 40 (82.5%) patients showing normal EMG. Seven (17.5%) patients showed residual abnormal EMG (Table 2).

(2) Analysis of postoperative QEMG parameters in abductor muscles after 6 and 12 weeks.

(Table 3):

QEMG parameters of G.Med

Duration: values at 6 weeks were higher with highly significant difference in comparison to baseline duration. There was also highly significant difference in duration after 6 weeks and after 12 weeks with no significant difference between baseline duration and after 12 weeks.

Amplitude: after 6 weeks, amplitude was significantly lower in comparison to baseline amplitude. There was significant difference between amplitude after 6 weeks and after 12 weeks with no significant difference between baseline amplitude and after 12 weeks.

Phase: showed no significant between different times of assessment.

QEMG parameters of G.Min

Analysis of duration showed similar finding as G.Med with significant differences. Amplitude showed no

Table 1 Comparison between Preoperative Quantitative electromyography parameters of G.Med, G.min and TFL of affected and normal side

Preoperative QEMG	Affected side (Mean±SD)	Normal side (Mean±SD)	*P*. value
Gluteus Medius			
Duration (ms)	26.54 ± 4.56	27.65 ± 3.7	0.236
Amplitude (uV)	584.27 ± 94.76	562.52 ± 35.1	0.177
Phase	5.92 ± 1.59	5.52 ± 0.3	0.122
Gluteus Minimus			
Duration (ms)	25.18 ± 3.96	26.33 ± 3.9	0.195
Amplitude (uV)	525 ± 97.04	549.52 ± 39.1	0.142
Phase	5.85 ± 1.03	6.1 ± 0.4	0.156
Tensor Fascia Lata			
Duration (ms)	25.11 ± 4.13	26.65 ± 3.7	0.083
Amplitude (uV)	551.53 ± 81.04	569.52 ± 35.1	0.201
Phase	5.81 ± 1.09	6.1 ± 0.3	0.109

Data expressed as mean ±SD. *P* value is significant if less than 0.05.

Table 2 Quantitative electromyography findings of all three muscles in patients preoperative and after surgery by 6 and 12 weeks

QEMG	Preoperative (*n*=40) No. (%)	6 w Postoperative (*n*=40) No. (%)	12 w Postoperative (*n*=40) No. (%)	*P*1	*P*2	*P*3
Normal	40 (100.0)	25 (62.5)	33 (82.5)	< 0.001**	0.018*	0.080
Abnormal	0	15 (37.5)	7 (17.5)			

*P*1: Comparison between preoperative versus postoperative % of normal Quantitative electromyography after 6 weeks.
*P*2: Comparison between preoperative versus postoperative % of normal Quantitative electromyography after 12 weeks.
*P*3: Comparison between postoperative (6weeks) versus postoperative (12 weeks) % of normal Quantitative electromyography.
** = highly significant difference. *=significant difference.

Table 3 Comparison between preoperative and follow-up Quantitative electromyography parameters of the affected abductors in total sample

QEMG parameters	Preoperative	6 weeks	12 weeks	*P*1	*P*2	*P*3
Gluteus medius						
Duration (ms)	26.54±4.56	30.33±6.36	25.43±4.21	0.003**	0.262	0.001**
Amplitude (uV)	584.27±94.76	536.48±88.51	576.06±70.54	0.013*	0.142	0.024*
Phase	5.92±1.59	4.62±1.86	4.76±1.51	0.440	0.428	0.859
Gluteus minimus						
Duration (ms)	25.18±3.96	27.42±5.83	25.81±3.88	0.048*	0.973	0.049*
Amplitude (uV)	525±97.04	505.42±92.59	527.67±71.43	0.359	0.889	0.242
Phase	5.85±1.03	3.9±0.22	4.49±1.16	0.009**	0.095	0.036*
Tensor fascia lata						
Duration (ms)	25.11±4.13	29.42±5.49	26.02±4.24	<0.001**	0.333	0.003**
Amplitude (uV)	551.53±81.04	545.56±96.37	562.2±71.2	0.765	0.533	0.383
Phase	5.81±1.09	5.52±1.41	4.6±1.57	0.056	0.367	0.022*

Values are presented in mean ±SD.
*P*1: Comparison between preoperative versus postoperative values after 6 weeks.
*P*2: Comparison between preoperative versus postoperative values after 12 weeks.
*P*3: Comparison between 6 weeks postoperative vs. 12 weeks' postoperative values.
** = highly significant difference. *=significant difference.

Table 4 Baseline electromyography among enrolled patients based on diagnosis

	OA (*n*=22)	FNF (*n*=18)	*P* value
Duration (ms)	26.53±4.56	23.80±8.69	0.13
Amplitude (uV)	584.26±94.75	583.80±84.45	0.45
Phase	5.92±1.58	4.02±2.85	0.11

Data expressed as mean±SD. *P* value was significant if less than 0.05.
FNF, fracture neck of femur; OA, osteoarthritis.

Table 5 Comparison between Quantitative electromyography results in patients with osteoarthritis and fracture neck of femur

Diagosis	OA hip	FNF	*P* value
Total Number	22	18	
Abnormal EMG 6 week (Acute denervation)	10 (45%)	5 (27.7%)	0.33
Abnormal EMG 12 weeks (Persistent denervation)	4 (18.1%)	3 (16.6%)	>0.99

P value is significant if less than 0.05. OA: osteoarthritis; FNF: fracture neck of femur.

significant differences between different times of assessments. The 6-week phase of G.Min muscle was significantly lower in comparison to preoperative value (highly significant). There was significant difference between 6weeks and after 12 weeks phase but with no significant difference between preoperative and 12 weeks phase.

QEMG parameters of TFL

Analysis of duration showed similar finding as G.Med. Amplitude of TFL muscle showed no significant differences between different times of assessments. Also, phase showed no significant differences between different times of assessments with exception of significantly higher phase at 6 weeks in comparison to 12 weeks.

Analysis of QEMG results according to diagnosis

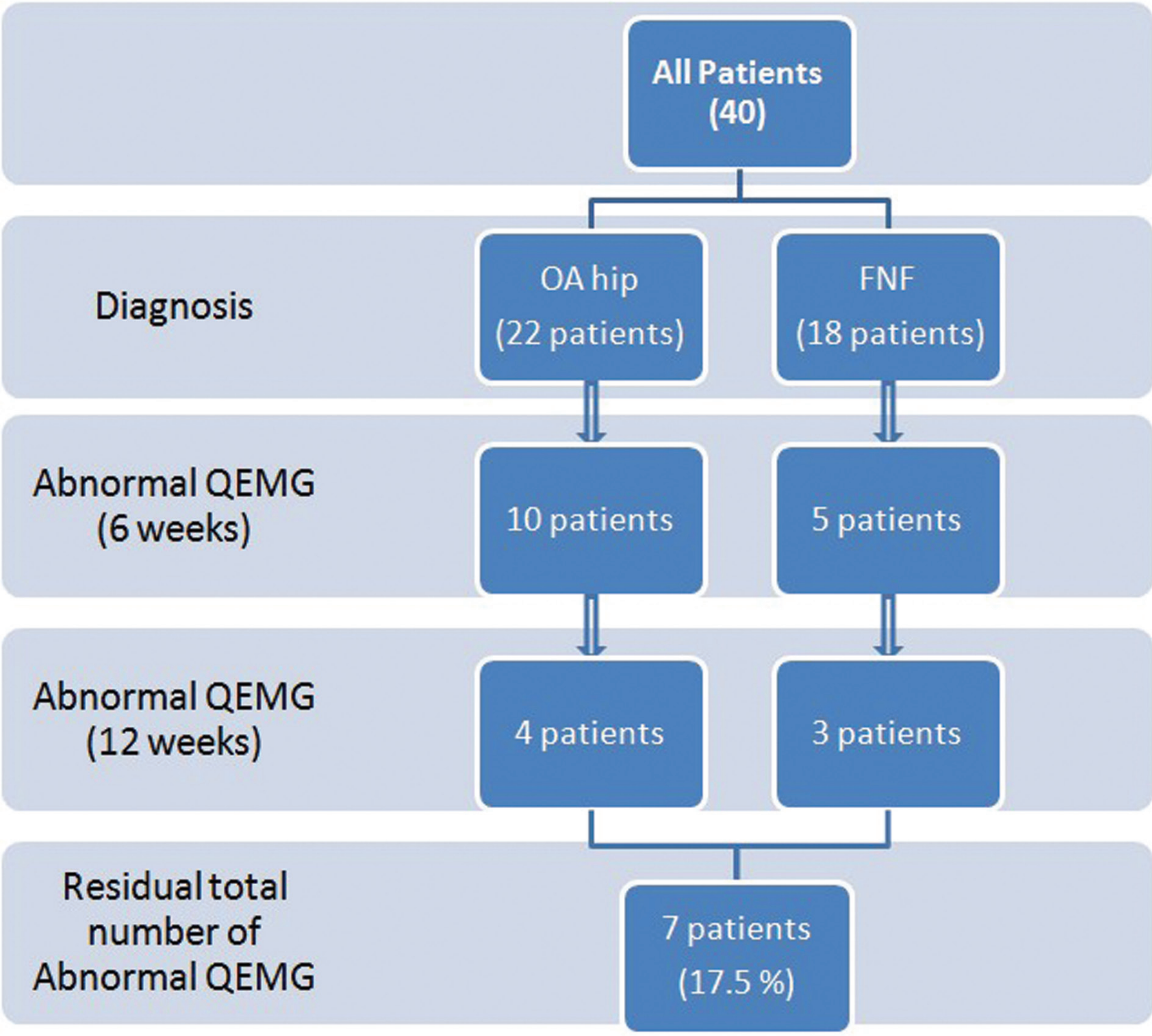
Baseline EMG among enrolled patients based on diagnosis

There were no significant differences between patients with OA and those with FNF as regards baseline duration, amplitude and phase (Table 4).

Postoperative QEMG results in patients with OA and FNF. In patients with OA (22), there was acute denervation of hip abductors (6 weeks) in 10 (45%) patients. After 12 weeks, there was persistent denervation in 4 (18.1%) patients. In patients with FNF (18), there was acute denervation of hip abductors (6 weeks) in 5 (27.7%) patients. After 12 weeks, there was persistent denervation in 3 (16.6%)patients with no statistical difference between the two groups (Table 5) and (Fig. 4).

Clinical Results: MRC grading. Nine out of 40 (22.5%) patients had weakness of abductor muscles at 12 weeks. All had grade 4-muscle power. All seven patients who had residual abnormal EMG examination had grade 4-muscle power. The other two patients with weakness had normal EMG examination. Trendelenburg test. At final follow-up, 14 patients out of 40 (35%) had positive Trendelenburg test. Of those, five patients had residual abnormal EMG and nine patients had normal EMG examination of abductor muscles.

Figure 4



Flowchart showing residual abnormal Quantitative electromyography in patients with osteoarthritis and fracture neck of femur.

Discussion

Postoperative abductor dysfunction following the direct lateral approach for hip arthroplasty has been reported in many studies [2,22,24,25,27].

It is multi-factorial, and the morbidity attributable to SGN injury is difficult to define [15,22,24,25]. Injury through the approach by extending the proximal split beyond the proposed 'safe zone' in the surgical approach is the direct cause of abductor denervation [9,13,42]. Other mechanisms are indirect due to stretching and positioning of the retractors during acetabular exposure or leg positioning during surgery [2,43]. Being multifactorial, the abductor weakness in our series was found clinically in 14 patients in the form of Trendelenburg gait despite that only five out of the 14 patients had residual abnormal EMG indicating that many other factors could contribute to this weakness other than SGN injury.

In the literature, the true prevalence of SGN injury is not clear. [13,15]. This is because diagnosis of SGN injury is dependent only on EMG of the supplied three muscles. It is a deeply situated nerve and hence needle electrical testing of nerve conduction velocity cannot be performed.

Another reason of confusion is that most studies do not report a preoperative baseline EMG for comparison with false positive findings in patients with previously acquired nerve damage [44].

In this study, abductors were examined on the operated and normal side prior to surgery. To improve the diagnostic efficiency of EMG, quantification was done by interference pattern analysis.

In the first postoperative follow-up after 6 weeks, 15 (37.5%) patients showed EMG evidence of acute

Table 6 Comparison of studies on superior gluteal nerve dysfunction in hip arthroplasty

	Baker and Bitounis 1989 [2]	Abitbol *et al*. 1990 [22]	Ramesh *et al*. 1996 [23]	Kenny *et al*. 1999 [24]	Picado *et al*. 2007 [25]	Moussazadeh *et al*. 2013 [20]	Chomiak *et al*. 2015 [26]	This study
Number of patients	79 patients	55 patients	81 patients	42 patients	40 patients	31 patients	70 patients	40 patients
Mean age	Not reported	57 years	71.6 years	69.8 years	59.5 years	53.5 years	66.2 years	56 years
Type of surgery	All THA	All THA	Hemi: 51 THA: 30	All THA	All THA	Resurfacing THA	All THA	All THR
Type of approaches used	Modified lateral (Dall's): 29 Hardinge: 29 Posterior: 21	Lateral: 45 Posterior: 10	Hardinge	Hardinge:23 Trans-trochaneric: 19	Hardinge	Modified transgluteal	Anterolateral 22 Transguteal: 33 Posterior: 15	Modified lateral
Preoperative evaluation	……………	All had normal EMG	……………..	(48%had abnormal EMG)	EMG: all are-ve Trendelenburg test: 50% +ve	Surface EMG	QEMG all normal	QEMG:all normal
Follow-up period	Three months	52 weeks	Up to 9 months	Three months	6 months	36 months	Three to nine months	Three months
+ve EMG twelve weeks post operative	Modified lateral: (3.4%) Hardinge: (17%) Posterior:(4.7%)	40% lateral 35% posterior	11%	Hardinge: 56% Trans-trochaneric: 47%	12.5%	no neural lesions of the inferior branch of the superior gluteal nerve	81.8% (42.4% of acute and 39.4% of late changes) for gluteus medius	17.5%
Further follow-up EMG	……………..	…………………	9 months follow-up +ve EMG: 11%	…………………..	6 months follow-up +ve EMG: 7.5%			……..…………

denervation. Spontaneous recovery occurred in 8 of 15 patients by 12 weeks, suggesting that these lesions are related to traction injury (neurapraxia) or partial axonal damage to the fibers. The remaining seven (17.5%) patients who had persistent denervation had partial denervation (mild affection) as stated from analysis of MUAPs. This result is slightly higher than that reported by and Baker and Bitounis (3.4%), Ramesh *et al*. (11%) and Picado *et al*. (12.5%), but less than that reported by Abitbol *et al*. and Kenny *et al*. (40% and 56%, respectively) (Table 6).

According to Farkas *et al*. [45], the most immediate benefit of QEMG (when properly performed) is the provision of more precise continuous values for features like duration, amplitude, and number of phases/turns.

At 6 weeks there was significant increase in duration of MUAPs in all three muscles. Long-duration MUAPs may be seen within several weeks or months, after re-innervation has begun [37].

Also there was significant decrease of amplitude of MUAP in G.Med muscle only. The integral value and mean amplitude are diagnostic of cases with chronic neuropathy [46].

At 12 weeks, these values were insignificantly different with the preoperative values signifying return of near normal muscle activity.

Denervation was present in all three muscles at 6 and 12 weeks. When compared with the control MUAP values before surgery, there were nearly consistent changes.

Our interpretation of these results is that direct injury to the inferior branch of SGN by the muscular split in the surgical approach is unlikely as this would have affected the G.Min and TFL more than G.Med as the former muscles are supplied by the terminal branches of the nerve. The anatomical variations in the branching patterns of the nerve [17,18,47] leaves a few terminal branches especially in the spray pattern vulnerable to injury in the surgical approach. The Proximal split in the modified lateral approach is intended to be more anterior to limit the G.Med muscle and tendon injury and even if it goes beyond the proximal limit, the nerve branches to the G.Med would escape injury.

Residual partial denervation of all gluteal muscles in seven patients was mild and the QEMG values were insignificantly different from their control values before surgery, indicating partial recovery from neurapraxia.

Positive Trendelenburg test and limp was evident in five out of the seven patients who had residual abnormal EMG. All patients had grade 4 abductor muscle power.

Baker and Bitounis [2], Abitbol *et al*. [22], Kenny *et al*. [24], and Picado *et al*. [25], Chomiak *et al*. [26]

found no correlation between EMG results and limp, positive Trendelenburg test and clinical problems. Other authors Ramesh *et al*. [23] and Sienbenrok *et al*. [43] found that persistent damage to the nerve was associated with a positive Trendelenburg test and abductor weakness.

Kovalak *et al*. [48] showed that fat atrophy of abductors on the operated side detected by MRI correlated with lower clinical results. Svensson *et al*. [33] showed that Trendelenburg gait was significantly increased only in the group of patients who had postoperative separation of the gluteal-vastus aponeurosis repair by more than 2.5 cm. Baker and Bitounis [2] similarly found that avulsion of the anterior gluteal flap from the greater trochanter is a major reason for postoperative abductor weakness.

Significant impairment of hip abductor strength (by isokinetic testing) was found as late as 2.5 years after surgery compared with the unoperated leg, in one study [20]. None of the patients; though, had positive Trendelenburg sign.

Limping and Trendelenburg gait is dependent on many factors besides muscle strength including anatomical and mechanical factors [2,49]. Postoperative abductor strength can be affected by preoperative abductor function and the conditions of the hip reconstruction, including the femoral offset and acetabular cup positioning [50].

The possible cause of confusion in the literature between the clinical results related to abductor muscle power, limp and positive Trendelenburg test can be explained by the complexity of function of the three individual muscles which are usually tested as a mass action. The G.Med muscle is divided into three different parts and GMin into two parts with separate nerve supply to each part. [49]. The G.Med is active in the stance phase and that the three parts of the muscle fire sequentially with different actions through the gait cycle [51]. The TFL is the major muscle that counter-balances the force of the body weight during the stance phase of the gait cycle [52,53] and prevents the Trendelenburg gait [54].

QEMG evaluation in patients included in this study who had FNF (18 patients, 45% of patients) showed no preoperative abnormality. Nerve injury following isolated FNF is very rare [55].

In both groups of OA and FNF, acute denervation of the SGN detected by QEMG at 6 weeks was partial, of mild intensity, and tended to improve spontaneously by twelve weeks postoperatively.

The difference in persistent denervation in the group of patients with FNF (16.6%) compared with that of the OA group (18.1%) was also statistically insignificant. For our knowledge this is the first study performed by QEMG on patients with FNF operated on by THA (Table 6).

By QEMG evaluation in the patients with residual abnormalities (17.5%), the changes found in MUAPs analysis were related in all patients to neuropathic origin. The possible factors related to the approach as physical damage of the gluteal muscle fibers and failure to reattach the tendon insertions on the greater trochanter which can give abnormal EMG findings were thus excluded. Either can lead to abductor weakness and dysfunction causing obvious limp.

Study Limitations:

Short follow-up as our protocol was guided by previous authors [2,23] who found that electrophysiological evidence of recovery at three months appeared to predict a full return of function.

Relatively small number of patients, as needle EMG examination is cumbersome for most patients and QEMG automated analysis taker longer time than QEMG for the same examination.

Conclusion

The QEMG evaluation showed that all three muscles are affected to the same degree confirming that partial denervation is related to SGN stretching during the exposure and not to direct injury of the terminal branches of the nerve through the incision in the muscle fibers. The hip abductors usually recover after the early postoperative period without major clinical disability.

Financial support and sponsorship

None.

Conflicts of interest

None.

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