Magnetic resonance-based hip muscles retrospective analysis shows deconditioning and recovery after total hip arthroplasty surgery

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TITLE PAGE

Magnetic Resonance-based hip muscles retrospective analysis shows deconditioning and recovery after Total Hip Arthroplasty Surgery.

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DECLARATIONS

Authors' contributions

Each author contributed in equal manner to the development of this paper. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The data that support the findings of this study are available from Istituto Ortopedico Rizzoli, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Istituto Ortopedico Rizzoli.

Consent for publication

Not applicable.

Ethics approval and consent to participate
The study has been approved by the local ethics committee (CE AVEC: 486/2020/Oss/IOR) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.
All persons gave their informed consent prior to their inclusion in the study.

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ABSTRACT

Purpose. To estimate the effect of unilateral hip osteoarthritis (OA) on hip muscles volume and fatty infiltration and to evaluate changes of muscles after Total Hip Arthroplasty (THA) surgery.
***Methods*.** A retrospective analysis was conducted on patients with unilateral hip OA subjected to THA with perioperative pelvic girdle 1.5T Magnetic Resonance Imaging (MRI). Thirty-five patients were included. Ten of these have also postoperative MRIs. Medius Gluteus (MG) and Iliopsoas (IP) muscles were manually segmented on the MRI scans, the corresponding 3D muscle geometries were reconstructed, and the volumes extracted. Muscle quality was assessed using the Goutallier classification on coronal MRI images. Volume and muscle quality differences were calculated between healthy and affected side.
Results. Pre-operatively, MG and IP on the affected side presented a mean muscle volume 17.5±18% ($p<0.001$) and 14.4±15.8%($p<0,001$) smaller than the healthy counterpart, respectively. Muscles on the affected side showed a significant higher grade of fatty infiltration compared to the healthy side ($p<0.05$ for MG; $p<0.001$ for IP). At an average follow-up of 13±5.3 months after THA, MG and IP muscles of the affected hip showed an average 22.8% ($p<0.001$) and 28.2% ($p<0.001$) volume increase after THA. Also, the healthy side showed a significant increase of muscle volume for IP (17.1% $p<0.001$). No significant change for MG muscle was observed.
Conclusions. The study demonstrated preoperative reduced muscle volume and higher fatty infiltration at the muscles of the OA hip compared to the contralateral healthy one. A significant positive effect of THA on hip muscles volume was observed. These findings give an interesting insight on muscle deconditioning and recovery in patients undergoing THA.

Keywords
Total Hip Replacement, Muscle deconditioning, Osteoarthritis, Fatty infiltration, Segmentation, Sarcopenia, Low Muscle Mass

Level of Evidence: IV

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INTRODUCTION

Total Hip Arthroplasty (THA) is the treatment of choice in patients with end-stage symptomatic osteoarthritis (OA) of the hip. Before surgery, patients are screened to identify any comorbidity or risk factor predisposing for complications, and surgery is tailored to achieve the best possible functional results (1,2).

Sarcopenia is a major health condition whose prevalence among orthopaedic patients is estimated to be around 40% (3,4). It is defined as a "syndrome of progressive and generalized loss of skeletal muscle mass and strength, with a risk of adverse outcomes including physical disability, poor quality of life and death"(5). Sarcopenia represents a major health condition in the elderly with high personal consequences; it carries a heavy economic burden for the healthcare system, given the increased costs of care during hospitalisation, the increased risk for long-term hospitalization and associated complications (6).

Sarcopenia is considered to be a risk factor for the development of OA and it is associated to lower functional outcomes after THA surgery: muscles deconditioning around the hip joint, typical of Sarcopenia, make conservative strategies less effective and anticipates the need for hip replacement (7); on the other hand, decreased hip muscles volume and increased fatty infiltration are strongly related to worse functional recovery outcomes after THA (1,2). Finally, OA-related immobility and disability is a recognized cause of hip muscles deconditioning and secondary to sarcopenia (8–11), thus creating a vicious circle.

Several studies have demonstrated the role of Sarcopenia, in particular the reduction of muscle mass, in predicting adverse outcomes and perioperative complications (2,12,13). There is a lack of data concerning local muscles status in the setting of hip OA, as well as the role of THA on muscle recovery. From this point of view, the role of imaging, and magnetic resonance imaging (MRI) in particular, although well established by current consensus (5), has not been exhaustively explored, nor its role in clinical and research setting established, given the complexity of measurement and interpretation of data.

Primary aim of the current study is to estimate the effect of unilateral hip OA on hip muscles status in patients who are candidate to THA surgery. Secondary aim of the study is to evaluate the modifications of hip muscles after THA surgery. These objectives are pursued by the evaluation of Medius Gluteus (MG) and Iliopsoas (IP) muscles volume, and their fatty infiltration measured through MRI at the healthy and pathological side and, when available, before and after THA surgery. To the best of the Authors knowledge, this is the first study aimed at muscles MRI assessment around a pathological hip joint, and the first to assess volume differences after THA in the setting of unilateral hip OA.

MATERIALS AND METHODS

Study design

A retrospective observational investigation was conducted on patients with unilateral hip OA subjected to THA with perioperative pelvic girdle MRI. The study was approved by the Institutional Review Board (CE AVEC: 486/2020/Oss/IOR) and was conducted in compliance with the Health Insurance Portability and Accountability Act and the Declaration of Helsinki.

Patients' selection

Our Institutional digital databases were queried for patients who underwent THA for unilateral hip OA from 2005 to 2019 with perioperative MRI of the pelvic girdle. Patients were searched and identified by a crossover comparison between our Institutional clinical records (patients who underwent THA) and radiological imaging database (patients with MRI of the pelvic girdle searched on PACS - Picture archiving and communication system). Identified patients were further screened considering specific exclusion criteria: not satisfactory MRI imaging (MRI imaging was considered satisfactory if: adequate IP and MG muscles volume measurements were feasible; MRI with poor image quality less than 1.5 Tesla, spatial resolution $<0.78 \times 0.78 mm^2$ and slice thickness >5mm; presence of artifacts due to metal implants compromising muscle identification); concomitant ipsilateral lower limb musculoskeletal disorders; neoplastic conditions; fractures; dysplastic hips. In case of multiple pre- or post-operative MRI, the closest to THA surgery or most recent were selected. Overall, 35 patients operated on 35 hips were identified and included in the study. Of these, 25 had only pre-operative MRI of the pelvis performed at an average 6±3.2 months before surgery, while 10 had both pre- and post-operative MRIs, performed 5.1±3.9 months before and 13±5.3 months after surgery, respectively. Patients' selection procedure is summarised in Figure 1.

Patients' demographics, time between MRI and THA (and vice versa, when available), diagnosis for THA, degree of OA according to Tonnis et al (14) were collected and reported (Table 1).

Muscles volume and quality measurement

MRI of the selected patients were retrospectively reviewed. IP and MG muscles were evaluated considering their recognized value in hip function. IP and MG muscle volumes were reconstructed using a manual MRI based muscle segmentation protocol (Figure 2), which had been internally tested for this purpose and was shown to provide repeatable results over time in terms of surface, shape and volume similarity (16). The segmentation procedure consisted in the subdivision of the volume of interest into voxels (the unit of measurement of the volume) with common characteristics, such as density and structural composition, and representative of distinct anatomical structures, via manual delineation of the individual muscle boundaries (16). Using the Mimics software (Materialise, Leuven, BE), the MG and IP muscles were manually segmented on the available T1-weighted MRI scans in the sagittal, coronal and transverse planes; consecutive planar (2D) segmentations were interpolated to obtain a 3D muscle volume. While the MG muscle volume was segmented in its entirety, the proximal part of the IP muscle (above the iliac crests) was removed and not accounted for in the analyses to minimize differences due to inconsistent scanned volume/scanning levels across patients and years. Such operation was standardized and automatically performed using a custom-written script in Python. Muscles volumes (in cm^3) were ultimately extracted and stored in a Microsoft Excel file (Microsoft Corporation, Redmond, WA) for later use and analyses.

Muscles quality was assessed on axial MRI images using the Goutallier classification (17) which allows to differentiate four grades of fatty infiltration (Figure 3). Volume and muscle quality differences between healthy and pathological side, and pre- and post-operatively were calculated considering the change in muscle volumes. Volume differences were calculated and hereby reported as percentage ratio.

Data analysis and Statistics
Data analysis was performed using Microsoft Excel (Microsoft Corporation, Redmond, WA) for Windows 10.
Continuous variables were reported as mean ± standard deviation (SD). Categorical variables were summarized as frequencies and percentages. Differences were assessed using the Fisher exact test for categorical variables and Mann-Whitney or Wilcoxon, when appropriate, for continuous variables. A p-value less than 0.05 was considered statistically significant.
Patients were stratified by sex, diagnosis for THA (primary arthrosis, secondary arthrosis, osteonecrosis), grade of osteoarthritis based on X-rays (15), weight and age and a multivariate analysis (ANOVA) was performed looking for significant differences.

RESULTS

Effect of unilateral hip OA on IP and MG
Preoperatively, MG and IP on the pathological side presented a mean muscle volume significantly smaller than the healthy counterpart by 17.5% and 14.4%, respectively (Table 2).

Patients' stratification also revealed that patients with primary degenerative arthritis presented with a significantly higher loss of MG muscle mass (mean difference 9,8%) compared to the other causes of THA, including osteonecrosis and secondary arthritis.

MG at the pathological side presented a significant higher grade of fatty infiltration compared to the healthy side according to the Goutallier classification, while no significant difference was found in the IP muscle (Table 3).

Effect of THA on IP and MG muscles
Ten patients (28.6%) had pre- and post-operative MRIs. At a mean follow-up of 13±5.3 months after THA, MG and IP muscles at the affected hip showed an average 22.9% ($p<0.001$) and 28.2% ($p<0.001$) volume increase after surgery, respectively. The healthy side showed a significant increase (17.1% $p<0.001$) in IP muscle volume, accompanied by a non-significant reduction (-2.7% $p>0.05$) of the MG volume (Table 4) (Figure 4).
Post-operatively, healthy and operated hip did not show significant differences in muscle volumes. Changes in fatty infiltration of the studied muscles showed to be non-significant, both in comparing pre- to post-operative values, and healthy to pathological side.

DISCUSSION

In the present study we evaluated muscles status on the pathological and healthy side in patients affected by unilateral hip OA before and after THA. IP volume measurement has been used because IP is likely to correlate with the patient's overall function; MG, on the other hand, well reflects the local conditions of the hip musculature, and it is known that THA performances are strictly related to MG function (15). We found a significant preoperative muscle volume loss and fatty infiltration at the affected hip in OA patients. Preoperatively**,** MG and IP muscles at the affected side resulted 17.5% and 14.4% smaller than the contralateral ones, respectively. Despite the limited number of patients, we also observed an encouraging positive effect of THA surgery on IP and MG muscles volume at an average 13 month follow up. These results are in agreement with the findings available in current literature (18–20), that demonstrated atrophy of the muscles around an arthritic hip when compared to the contralateral side. Only one study to date (20) used a cross-sectional MRI imaging and 3D volume reconstruction, showing MG volume differences as high as 12% in severe unilateral hip OA. In other studies(18,19), however, these differences were assessed using the cross sectional area and the radiological density through CT scans.

At an average 13-month follow-up after THA surgery, MG and IP of the affected hip showed an average 22.9% and 28.2% significant volume increase, respectively. At the same timepoint, the IP muscle of the healthy hip showed a significant increase (17.1%) of muscle volume, while non-significant volume changes (-2.7%) were observed in the healthy MG muscle postoperatively. The increase in the volume of the IP muscle also at the unaffected side might be related to a better overall mobility and function of the patients. Muscle volume recovery after THA has been described in previous studies (20,21). Uemura et al (21) reported a significant increase (11%) of MG muscle volume 2 years after THA implant, together with a reduction (-8%) in muscle volume at the contralateral side. In the study, the cross-sectional area was used as a surrogate of muscle volume, accepting the risk of bias on muscle measurement. Xu et al (22) reported differences in muscle volume after THA in a study in which they tried to demonstrate a different hip muscle recovery when different types of femoral stem implants are used. At 6 months postoperatively, they could not show differences among different stems groups, but demonstrated a consistent increase, ranging from 7 to 8.2%, in the average MG muscle volume in operated patients.

As regards the impact of THA surgery on patients' muscles, our study is the first to report MRI derived data of hip muscles volumes and fatty infiltration in the setting of unilateral hip OA. We found that a positive muscle volume increase after THA was observed. Encouraging preliminary reports should be carefully translated into clinical practice. Loss of muscle mass in the setting of hip OA can be a partially reversible cause of disability, and it may benefit from interventions that improve function, including THA surgery. The role of physical rehabilitation in this setting cannot be overstressed, together with nutritional interventions and pharmacological approaches (10). In the present study, THA alone has demonstrated a significant impact on IP and MG muscles volumes, suggesting a potential contribution of THA surgery in improving the function of patients affected by hip OA. Total joint replacement can contribute to this process by decreasing pain and improving mobility and function, contributing to the improvement in the quality of life of operated patients (23).

This study presents several limitations: the retrospective nature, the lack of a control group, and the absence of clinical data or functional scores.

The strict application of inclusion and exclusion criteria led to a reduced study population; however, the statistical analysis outlined significant differences among groups. The risk of selection bias must be considered: the inclusion criteria (presence of pelvic girdle MRI) led to a high prevalence of osteonecrosis and a younger age of selected patients who were candidate to THA in respect to those affected by OA. Patients' diagnosis leading to THA surgery was related to muscle mass loss: patients with primary OA showed higher differences in muscles volumes when compared to those affected by osteonecrosis. This finding may be related to the long-lasting history of degenerative disease of the hip compared to the osteonecrosis, which usually shows a faster development of symptoms and need for joint replacement. The increased prevalence of osteonecrosis in our study population may be related to the availability of MRI imaging, which is performed in the suspect of avascular necrosis, but rarely performed in OA patients preoperatively. The significance of muscle volume alone in predicting physical performances and outcomes is debated (25); moreover, volume measurements just allow a comparison of the percentage ratio between the healthy and pathological side in the same individuals, and to evaluate variations of the same muscle at different timepoints. These precluded a comparison of different patients given the lack of standardized tool, and normalized, anthropometric-based measurements. The inclusion of a qualitative analysis of MG and IP according to the Goutallier classification partly overcame this limitation: fatty infiltration estimation has been appropriately correlated with functional outcomes (26) and, given the absolute value assumed by the Goutallier score, it allows for a direct comparison of different patients. In our study, MG appeared to be much more affected by OA-related in terms of volume reduction and fatty infiltration.

In conclusion, this study demonstrated a reduced muscle volume and higher fatty infiltration at the MG and IP muscles of the OA hip before THA surgery compared to the contralateral healthy one. A significant positive effect of THA surgery on IP and MG muscles volume was observed: MG muscles volume after surgery averaged values measured at the contralateral healthy side; as regards IP muscles, volumes of both sides increased significantly showing a positive relation to patients' function.

These findings give an interesting insight into muscle deconditioning and recovery in patients undergoing THA surgery and pose the basis for future research on Sarcopenia. The impact of MG and IP muscle volume variations on functional outcomes is still to be assessed. We support the implementation of MRI based protocols in the diagnosis and evaluation of muscle volumes, fatty infiltration, and loss of muscle mass. Future prospective investigations with a larger cohort of patients and a matched control group could help clarify these issues and improve the standard of care of hip OA patients and improve our understanding on the effect of THA surgery in the aged.

Abbreviations

OA: osteoarthritis; THA: Total Hip Replacement; MRI: Magnetic Resonance Imaging; MG: Medius Gluteus; IP: Iliopsoas.

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TABLES

Table 1

	All patients	*p*-value
Patient	35	
Age at surgery (years)	55.9±19.5	**0.09+**
Sex	17 F; 18 M	0.98++
Time: MRI to THA (months)	6±3.2	0.83+
Time: THA to MRI (months)	13±5.3	0.22+
Diagnosis for THA(n:%)	Primary OA (57.1%) Secondary OA (5.7%) Osteonecrosis (37.1%)	**0.029++**
Degree of OA* (n:%)	I (6:17.1%) II(17:48.6%) III (12:34.3%)	0.44++

Table 1: Patients' demographic and data. MRI = Magnetic resonance imaging, OA = Osteoarthritis, THA = Total hip arthroplasty.
***According to Tonnis classification. +Mann Whitney test. ++Fisher exact test. In bold statistical significance (p<0.05).**

Table 2

	Volume differences ± SD	p-value
MG	17.5±18	**<0.001**
IP	14.4±15.8	**<0.001**

Table 2: Volume differences between healthy and pathological side for the Iliopsoas (IP) and Medius gluteus (MG) muscles in patients with unilateral hip osteoarthritis. Results are reported as percent values. SD = standard deviation.
+Mann Whitney test. In bold statistical significance (p<0.05).

Table 3

	All patients		
	Healthy hip	Pathological hip	p-value+
MG Fatty infiltration* Grade(n:%)	0 (2:5.7%) I (20:57.1%) II (10:28.6%) III (3:8.6%)	0 (1:2.9%) I (8:22.9%) II (18:51.4%) III (8:22.9%)	**0.018**
IP Fatty infiltration* Grade(n:%)	0 (19:54.3%) I (15:42.9%) II (1:2.9%) III (0:0%)	0 (5:14.3%) I (12:34.3%) II (16:45.7%) III (2:5.7%)	**<0.001**

Table 3: Fatty infiltration in the Iliopsoas (IP) and Medius gluteus (MG) muscles on the healthy and pathological side in patients with unilateral hip.
*** According to Goutallier classification. +Fisher exact test. In bold statistical significance (p<0.05).**

Table 4

	Percentage ratio differences ± SD in all patients	p-value+
MG of the affected side	22.9±21.2	**<0.001**
MG of the healthy side	-2.7±23.8	0.78
IP of the affected side	28.2±23.2	**<0.001**
IP of the healthy side	17.1±19.1	**<0.001**

Table 4: Percent differences between pre- and post-operative Iliopsoas (IP) and Medius gluteus (MG) muscle volume. SD = standard deviation.
+Mann Whitney test. In bold statistical significance ($p<0.05$).

FIGURES

Fig.1

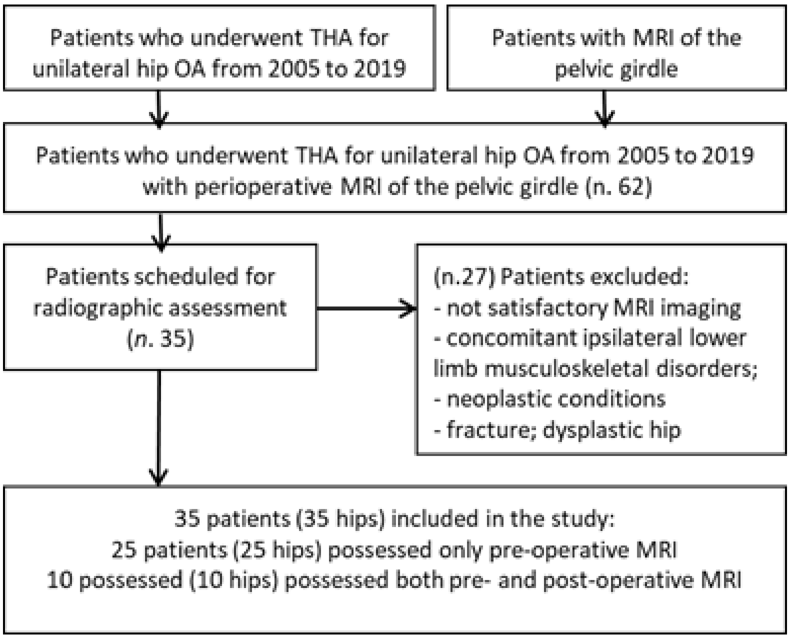

Figure 1: Flow chart showing patients' selection procedure

Fig.2

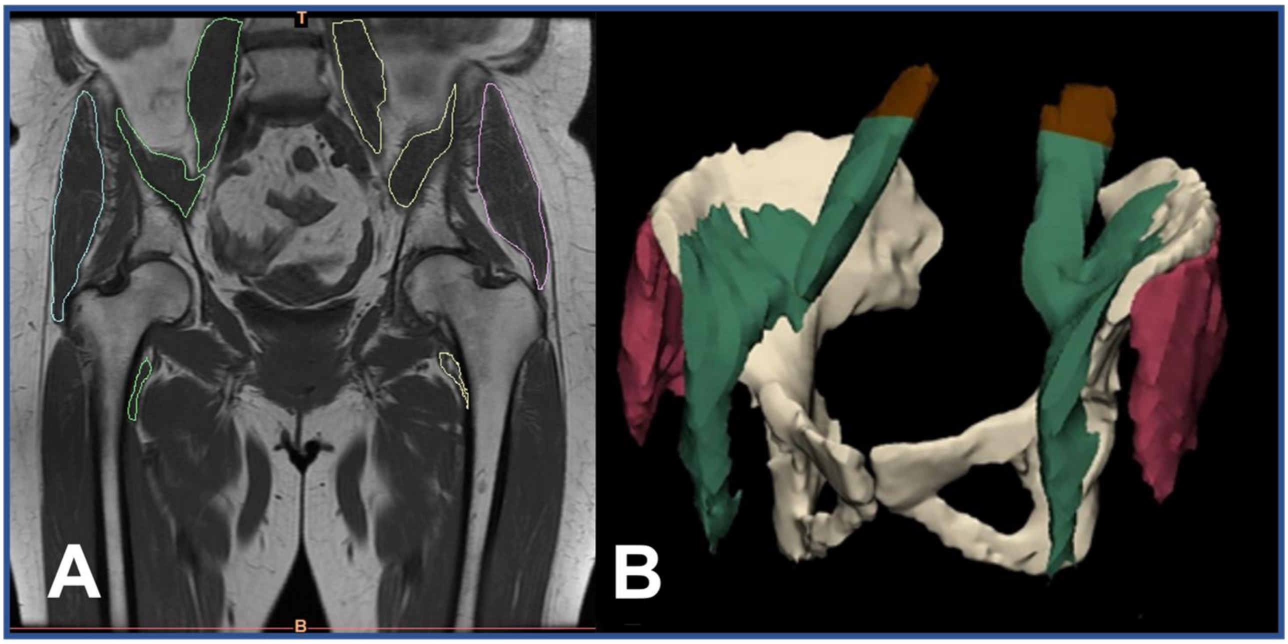

Figure 2: Example of muscle volume segmentation: (A) T1-weighted coronal MRI scan of the pelvic area with coloured manually drawn boundaries of the muscles of interest. (B) 3D muscle geometry reconstructed via interpolation of consecutive 2D segmentations; the IP volume was considered distal to the iliac crest, as represented in green in the B image. MRI = Magnetic resonance imaging, IP = Iliopsoas.

Fig.3

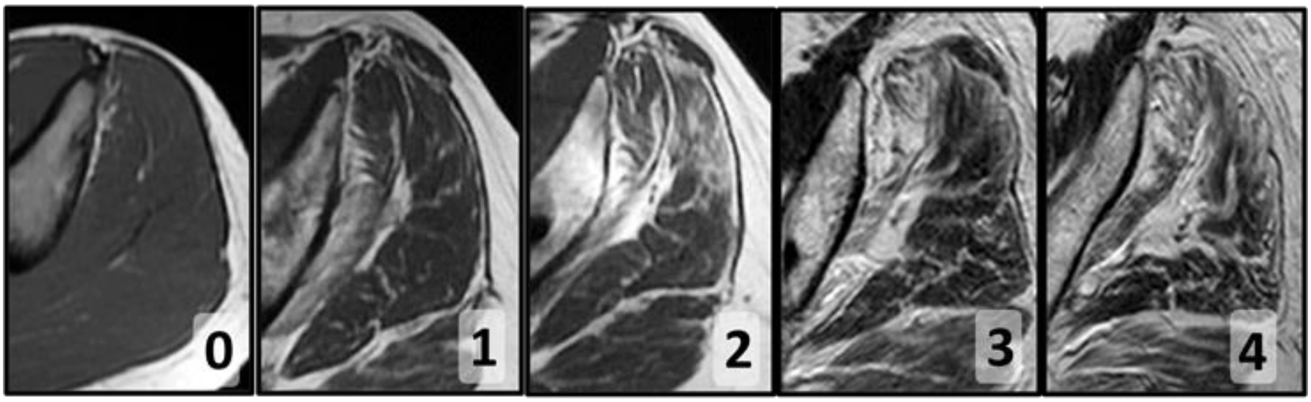

Figure 3: MG muscle quality assessment using the Goutallier classification: grade 0, normal muscle quality; grade 1, in which muscle contains some fatty stripes; grade 2, with fat infiltration, but still more muscle than fat; grade 3, equal amounts of muscle and fat; and grade 4, more fat than muscle

Fig.4

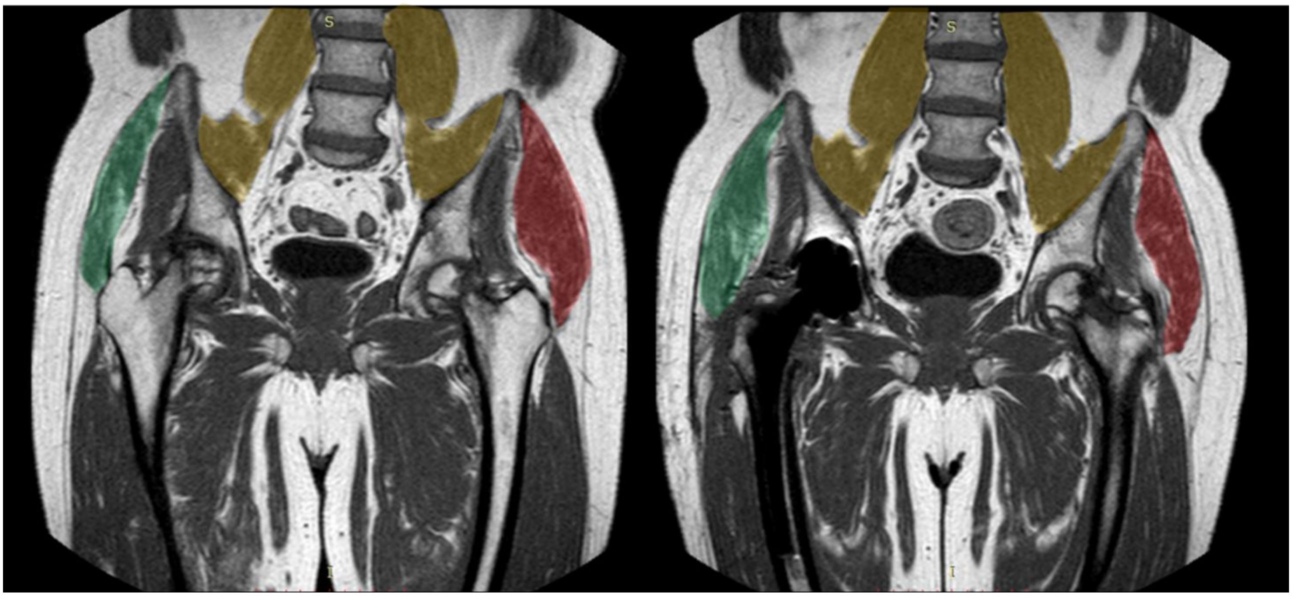

Figure 4: On the left, pre-operative T1 coronal MRI of a 65y male patient with OA of the right hip. On the right, a T1 coronal MRI of the same patient 14 months after THA of the right hip, showing an increase in volume for the MG muscle on the affected side (in green) and for the IP muscle on both sides (in yellow). Of note, after THA, the volume of the MG muscle on the healthy side is smaller (in red).