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NUCLEAR MEDICINE

Clinical value of a [18F]-FDG PET-CT muscle-to-muscle SUV ratio for the diagnosis of active dermatomyositis

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Abstract

Objective To study a muscle-to-muscle standardised uptake value (SUV) ratio with FDG-PET/CT (FDG-PET) as a marker for the detection of disease activity in dermatomyositis (DM).

Methods Patients with DM ($n = 24$) who met the *European Neuro-Muscular Centre* diagnostic criteria were retrospectively identified over a 3-year period through a national survey. Muscle biopsy was performed in all patients. Maximum SUV was measured in proximal muscles (SUV_{PROX}) that had the highest radiotracer uptake on visual grading as well as in the musculus longissimus thoracis (SUV_{MLT}), whereas mean SUV was measured for the liver (SUV_{LIV}). Muscle-to-liver SUV ratios for either muscle group were compared and a SUV_{PROX}/SUV_{MLT} ratio was calculated. SUV_{PROX}/SUV_{MLT} of DM patients were compared with age- and sex-matched control subjects ($n = 24$) with melanoma who had received FDG-PET scans.

Results DM patients presented with proximal and symmetrical muscle uptake. Differences in SUV_{PROX}/SUV_{LIV} and SUV_{MLT}/SUV_{LIV} ratios in DM subjects were significant ($p < 0.001$). SUV_{PROX}/SUV_{MLT} ratios in DM and their controls also differed significantly ($p = 0.0012$). The SUV_{PROX}/SUV_{MLT} ratio threshold between DM subjects and controls was 1.73 with a sensitivity of 50% (CI95%, 29.1 to 70.9%) and specificity at 83.3% (CI95%, 62.6 to 95.3%). When amyopathic DM patients were removed from the analysis, specificity was increased to 95% (CI95%, 75.1 to 99.9%) with a likelihood ratio of 10 and an AUC of 83.4% (CI95%, 71.4 to 95.4%).

Conclusion A muscle-to-muscle SUV_{PROX}/SUV_{MLT} ratio with a cut-off value of 1.73 in FDG-PET imaging might serve as a non-invasive marker to determine disease activity in dermatomyositis.

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Key Points

- *[18F]-FDG PET-scanner standardised uptake value (SUV) could reflect disease activity in dermatomyositis (DM).*
- *A ratio of SUV in proximal muscles (SUV_{PROX}) to SUV in musculus longissimus* thoracis *(SUV_{MLT}) could be used to determine active DM.*
- *Active disease is suspected for SUV_{PROX}/SUV_{MLT} ratios greater than 1.73.*

Keywords Positron-emission tomography · Fluorodeoxyglucose F18 · Myositis · Dermatomyositis · Amyopathic dermatomyositis

Abbreviations

DM	Dermatomyositis
ENMC	European Neuro-Muscular Centre
IMM	Idiopathic inflammatory myositis
MAA	Myositis-associated autoantibodies
MSA	Myositis-specific autoantibodies
SUV	Standardised uptake value
SUV_{LIV}	SUV of the liver
SUV_{MLT}	Musculus longissimus thoracis SUV
SUV_{PROX}	Proximal muscles SUV

Introduction

Dermatomyositis (DM) is a rare idiopathic inflammatory myositis (IIM) [1]. It has been known to be associated, though not exclusively, with other autoimmune connective tissue disorders such as systemic sclerosis, Sjögren's disease and/or systemic lupus erythematosus. Extra-muscular manifestations include pulmonary fibrosis and neoplastic disease. As a fact, cancer-associated DM has been described since 1916 and is identified in a third of cases [2, 3].

Muscle biopsy is an invasive procedure but a key element for the diagnosis and evaluation of disease activity in DM/IIM combined with clinical features [4]. Histological features can be normal or uninformative in up to 20% of cases and thus do not represent the overall activity of the disease [5]. The most used classification criteria—that of the *European Neuro-Muscular Centre* (ENMC)—recognise magnetic resonance imaging (MRI) of the muscles as a reliable imaging technique for characterising myositis [4]. Despite some conflicting data, MRI seems to be able to identify active disease and has recently been shown to predict patients with DM [6, 7]. Furthermore, biopsy-guided MRI seemed to yield better results when MRI was used as a triage test [8]. Similarly, fluorine-18 fluorodeoxyglucose ([18F]-FDG) positron emission tomography (FDG-PET) has been assessed in IIM—with previous studies reporting significant tracer muscle uptake that may reflect IIM activity [9–12]. FDG-PET appears to be a logical alternative to routine MRI that is a lengthy procedure, but does not cover all proximal muscles due to limited fields-of-view and resolution [6, 13].

In practice, however, FDG-PET is mostly performed in DM for the detection of cancerous lesions in cases of suspected paraneoplastic syndromes [14–16]. It is thus of interest to the clinician to combine this aspect of FDG-PET with a functional assessment of DM activity without the systematic need for muscle biopsy—especially when disease relapse is suspected.

Standardised uptake value (SUV) ratios with region-of-interest (ROI), such as the liver or mediastinal vessels, have been described in a limited number of patients but lacked sensitivity to detect muscle inflammation [9, 12]. Other methods such as a global calculation of SUV, though of interest, seem too complex for daily clinical practice [11].

The aim of our work was to study a simple ratio of muscle SUV that could reflect disease activity through the identification of muscle inflammation in DM.

Materials and methods

Patient inclusion and definitions

This retrospective and multicentric study was conducted through a national survey with the participation of French teaching and general hospitals over a 3-year period spanning from January 2013 to January 2016.

Subjects were included if they presented with DM that met the 2004 ENMC criteria and had had a muscle biopsy [4]. FDG-PET had to be performed within 3 months of diagnosis. Patients with anti-aminoacyl-transferRNA synthetase antibodies (anti-synthetase syndrome) or with autoimmune necrotising myositis were excluded from the onset.

A case-report form was sent to all participating centres to record clinical, biological and pathological data. Radiological and electromyography descriptions were also assessed when available. In accordance with French regulation, approval of the institutional review board was not required but the data were collected, stored and handled anonymously as is usually the case in retrospective studies.

DM was classified as *definite*, *probable* or *amyopathic* based on the ENMC criteria [4]. Muscle strength was assessed according to the Medical Research Council (MRC) scale. Cancer-associated DM was defined by the discovery of a neoplastic event within 3 months from the diagnosis of the IIM.

DM patients were further matched, on the basis of age and sex, with control subjects. The latter were melanoma patients for whom "full body" FDG-PET was performed for disease staging.

Biological features

Plasma levels of creatine phosphokinase (CPK) and, when available, aldolase, were recorded as multiples of the upper reference limit. Myositis-specific autoantibodies (MSA) were identified using immunodot assays (Euroimmun) when available. Anti-Mi2, anti-MDA5 (melanoma differentiation-associated gene 5), anti-TIF1γ (transcriptional intermediary factor 1-γ) and anti-NXP-2 antibodies were specified when positive. Myositis-associated autoantibodies (MAA) were also reported.

FDG-PET scanning and analysis

The different FDG-PET cameras were as follows: General Electric Medical System Discovery ST 610/690 ($n = 19$), Philips Gemini TF ($n = 4$), Siemens Biograph mCT40 ($n = 1$). SUV measurements were done using Xeleris 2 processing and review workstations.

Despite patient preparation and imaging protocols being specific to each centre, imaging acquisition was systematically performed at 60 min post-injection and at rest. Capillary glycaemia was less than 6.5 mM in all patients. Full body scanning was not a requisite.

Maximum SUV was measured in proximal muscles (SUV_{PROX}) that had the highest radiotracer uptake on visual grading as well as in the *musculus longissimus thoracis* (SUV_{MLT}), in the lumbar region. The choice of the proximal muscle was left to the discretion of the nuclear medicine specialists. In addition, the mean SUV of the liver (SUV_{LIV}) was measured. A two-dimensional ROI with a 20-mm diameter was used for muscle regions, whereas a 30-mm diameter was preferred for the liver parenchyma (Fig. 1). All SUV were adjusted according to body weight.

To characterise the reproducibility of the SUV measures and the muscle-to-liver ratio, a centralised re-read of FDG-PET exams was performed in patients for whom digital imaging files were available (validation cohort). The re-reading was done independently by two nuclear medicine physicians who were blinded to clinical and biological data. Xeleris 2.1. (Volumetrix) and Advantage (General Electric Medical System) workstations were used. The re-read also specified muscle regions in which radiotracer uptake was maximal.

Muscle-to liver SUV ratios for either muscle group were measured and compared. A SUV_{PROX}/SUV_{MLT} ratio was then calculated to differentiate between patients with active myositis and those with amyopathic forms of the disease.

Statistical analysis

Continuous variables are expressed as median values with their interquartile range (IQR). Extreme values are specified when necessary.

Bland-Altman plots were used to study the interobserver reproducibility of FDG-PET SUV measures. The differences between SUV ratios for a given patient were analysed using the Wilcoxon signed-rank test. Correlations between the FDG-PET SUV and CPK levels were evaluated with Spearman's rank-order correlation test. Classifier performance was assessed with a receiver operating characteristic (ROC) curve—the preferred classifier being the SUV_{PROX}/SUV_{MLT} ratio. The Mann-Whitney test was used to study differences between continuous variables from different groups.

A p value < 0.05 was considered statistically significant; 95% confidence intervals (CI) are specified. All statistical analyses were performed using GraphPad Prism Software version 7.0 (GraphPad Software, 2016) and Microsoft Office Excel 2016.

Results

Patient characteristics and FDG-PET findings

Twenty-four patients from 11 participating centres were included. Diagnoses of DM were established between June 2010 and May 2015. Seventeen patients were classified

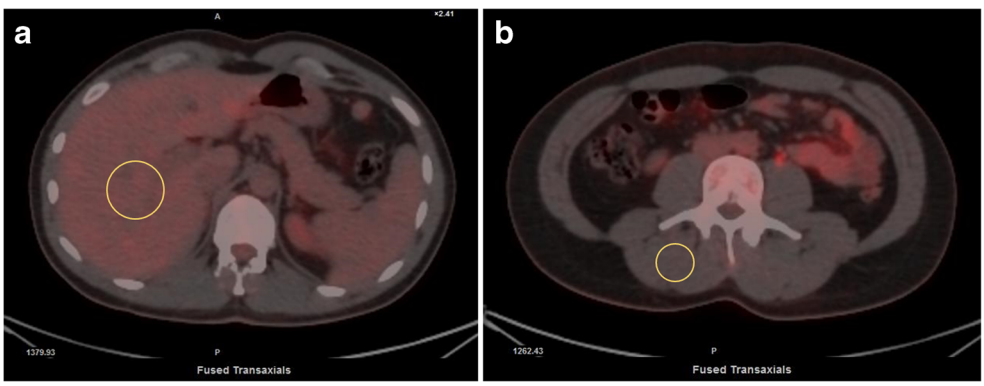

Fig. 1 Examples of ROI measurements (orange circle) in representative FDG-PET images of a control patient. A two-dimensional ROI with a 30-mm diameter is used for assessing mean SUV of the liver (**a**), whereas a 20-mm diameter was preferred for grading muscle uptake in the musculus longissimus thoracis in the lumbar region (**b**) and in proximal muscles (not shown)

Table 1 Patient characteristics

Patient characteristics	*N*	Values
Women/men, *n*/*n*	24	17/7
Age, median years (extreme values)	24	63 (27–85)
"Definite" DM according to ENMC criteria, *n*	24	18
DM sine dermatitis, *n*	24	2
DM amyopathic (sine myositis), *n*	24	4
Clinical severity, *n*	24	11
Clinical suspicion of cancer, *n*	24	3
Myalgias, *n*	24	21
Muscle weakness	24	
Semi-quantitative scale, median (IQR)	24	2 (1–2.8)
mMRC scale, median (IQR)	24	3 (3–4)
Biological myolysis		
CPK, median of multiples of the upper reference limit (IQR)	24	14 (3–39)
Aldolase, median of multiples of the upper reference limit (IQR)	12	1.9 (1–8.1)
Myositis-specific antibodies, *n*	19	12
Anti-TIF1γ, *n*	19	1
Anti-MDA5, *n*	19	2
Anti-NXP2, *n*	19	2
Anti-Mi2, *n*	19	7
Myositis-associated antibodies, *n*	24	5
Patients treated at the time of FDG-PET, *n*	24	9

n, number of patients; *N* number of subjects tested for the given characteristic; *DM*, dermatomyositis; *ENMC*, European Neuro-Muscular Centre; *mMRC*, modified Medical Research Council; *IQR*, interquartile range; *CPK*, creatine phosphokinase; *FDG-PET*, fluorine-18 fluorodeoxyglucose (FDG) positron emission tomography (FDG-PET)

as having "definite" DM (Table 1). There were 4 cases of amyopathic DM and 3 cases of DM *sine dermatitis*.

Nearly half of all patients (11/24) presented with life-threatening clinical signs at the time of diagnosis (pseudobulbar palsy ($n = 4$), respiratory failure ($n = 3$), or not specified ($n = 4$)). Biochemical and immunological characteristics are presented in Table 1, with FDG-PET findings in Table 2.

MSA were reported in only 19 patients. Anti-TIF1γ antibodies were positive in one case of synchronous colonic adenocarcinoma and small cell lung cancer. MAA were present in 5 cases: anti-citrullinated protein ($n = 1$), anti-DNAds ($n = 1$) and anti-SSA ($n = 3$) antibodies.

CPK levels were increased in all but the 4 cases of amyopathic DM. The SUV ratios did not correlate with CPK levels with $r = 0.20$ (CI95%, − 0.23 to 0.57; $p = 0.3397$) and $r = 0.0013$ (CI95%, − 0.41 to 0.42; $p = 0.9952$) for SUV_{PROX}/SUV_{LIV} and SUV_{PROX}/SUV_{MLT}, respectively (Annex 1).

All but for those with amyopathic DM had an [18F]-FDG muscle uptake that was symmetrical and proximal as illustrated on maximum intensity projections (Fig. 2). Control patients did not present with this characteristic [18F]-FDG uptake.

The median time from diagnosis to FDG-PET was 13 days (IQR, 7–21) (Table 2). None of the patients was diabetic nor under insulin therapy. Nine patients had either immunosuppressive treatment ($n = 2$) and/or corticosteroids ($n = 8$) for DM at the time of FDG-PET. One patient was on hydroxychloroquine alone for amyopathic DM.

Overall, 7 cancers were diagnosed. Extramuscular manifestations of DM ($n = 4$) were mostly pulmonary features with three cases of interstitial lung disease, and one case of tuberculosis.

All control patients ($n = 24$) presented with an evolutive form of melanoma. There was no clinical nor biological sign of rhabdomyolysis. Median age was 63 years (IQR, 53–72). The median injection-to-scan time was 60 min (IQR, 57–68). None was diabetic and capillary glycaemia was 5.5 mM (IQR, 5.01–6.00). Median SUV_{PROX}, SUV_{MLT} and SUV_{LIV} were, respectively, 1.4 g/mL (IQR, 1.2–1.6), 2.1 g/mL (IQR, 2.0–2.5) and 0.70 g/mL (IQR, 0.60–0.88).

Muscle biopsy sites and pathological analysis

Muscle biopsy was performed in high uptake territories in all but two cases and was inconclusive in one case. The deltoid muscle was preferentially selected for sampling ($n = 11$) whereas the *quadriceps femoris* was biopsied in 8 cases. The biopsy site was not specified in 5 cases. Pathological studies were compatible with DM in 22 specimens, including 4 cases of amyopathic DM. In the 2 remaining cases, pathological

analysis was not typical of DM but did not modify the ultimate diagnosis of DM. There was no evidence of constitutional myopathy or inclusion body myositis.

Interobserver concordance in the validation cohort

Interobserver reproducibility of FDG-PET SUV measures was conducted in 16 patients (Fig. 3). The Bland-Altman plots showed acceptable levels of agreement between both observers apart from the one outlier for SUV_{LIV}. Bias was not consistent as shown in the diagrams.

Studies of SUV ratios

All 24 patients presented with a characteristic proximal and symmetrical [18F]-FDG muscle uptake. The difference between muscle-to-liver ratios was statistically significant between the SUV_{PROX}/SUV_{LIV} and SUV_{MLT}/SUV_{LIV} ratios in DM subjects ($p < 0.001$) (Fig. 4). A SUV_{PROX}/SUV_{MLT} was then calculated for DM subjects and their controls; the difference between groups was statistically significant ($p = 0.0012$) (Fig. 5).

The SUV_{PROX}/SUV_{MLT} ratio was also calculated in patients with amyopathic DM ($n = 4$) and compared with that of DM patients with active muscle involvement ($n = 20$). There was no significant difference in muscle SUV ratios between these two groups ($p = 0.079$). We, however, established a SUV_{PROX}/SUV_{MLT} threshold of 1.72 under which amyopathic or non-active disease could be suspected.

Similarly, the SUV_{PROX}/SUV_{MLT} threshold between DM subjects and controls was 1.73. Sensitivity was 50% (CI95%, 29.1 to 70.9%) and specificity at 83.3% (CI95%, 62.6 to 95.3%) with an area under (AUC) the ROC curve of 76.6% (CI95%, 63.0 to 90.3%) (Fig. 6). When amyopathic DM patients were removed from the analysis, specificity was increased to 95% (CI95%, 75.1 to 99.9%) with a likelihood ratio of 10 (versus 3) and an AUC of 83.4% (CI95%, 71.4 to 95.4%) (Annex 2).

Of interest, the only patient with amyopathic DM with a SUV_{PROX}/SUV_{MLT} greater than 1.72 was under hydroxychloroquine at the time of the exam.

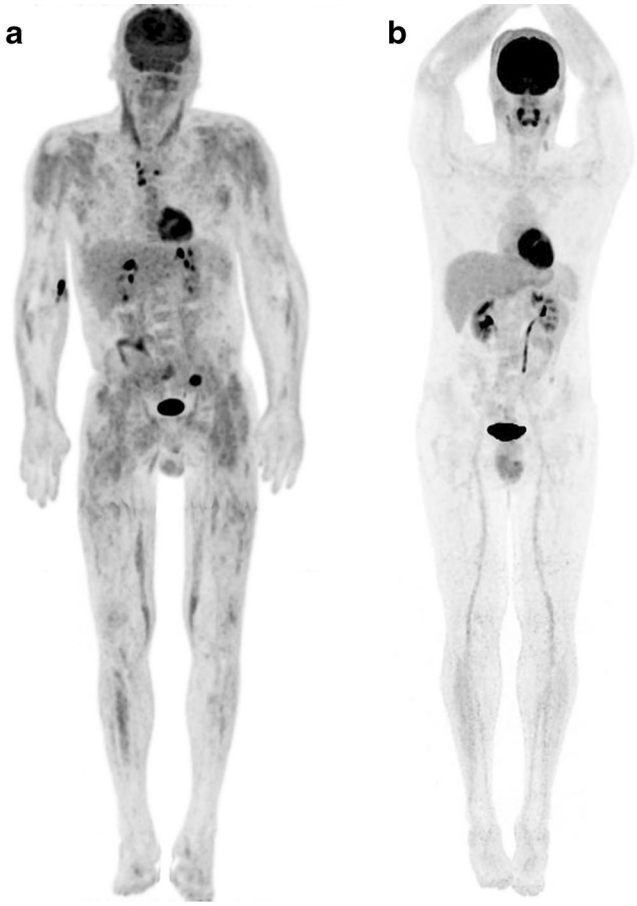

Fig. 2 FDG-PET maximum intensity projection in a dermatomyositis patient (**a**) and a control patient (**b**). Patient in **a** presents proximal and symmetrical [18F]-FDG muscle uptake with a hypermetabolic colonic focal lesion and suspicious mediastinal lymph nodes. Patient in **b** presents [18F]-FDG physiologic uptake without pathologic lesions

Discussion

This study has been able to provide more insight into the usefulness of FDG-PET in the semi-quantitative evaluation of muscle inflammation in DM. We have shown an original

Table 2 FDG-PET findings

FDG-PET findings	*N*	Median value (IQR)
Interval between diagnosis and FDG-PET, days	24	13 (7–21)
Treatment duration at the time of FDG-PET, days	9	15 (9–24)
Post-FDG injection time, minutes	20	70 (62–80)
SUV_{PROX} (g/mL)	24	3.7 (2.6–5.4)
SUV_{MLT} (g/mL)	24	2.1 (1.6–2.6)
SUV_{LIV} (g/mL)	24	1.2 (0.93–1.5)

N, number of subjects tested for a given finding; *IQR*, interquartile range; *FDG-PET*, fluorine-18 fluorodeoxyglucose (FDG) positron emission tomography (FDG-PET); *SUV*, standardised uptake values; SUV_{PROX}, maximal SUV in proximal muscles; SUV_{MLT}, maximal SUV in musculus longissimus thoracis; SUV_{LIV}, mean SUV of the liver

approach that refines the observers' analysis of tracer uptake by establishing a SUV ratio of SUV_{PROX}/SUV_{MLT}.

A ratio of muscle-to-muscle SUV: reflection of disease activity?

This study has shown that the uptake of [18F]-FDG was systematically seen in the proximal muscles of DM subjects. This observation is consistent with previous studies that have already raised the question of a relationship between elevated muscular SUV and the severity of IIM [9, 11, 12].

Due to the multicentric design of the study, FDG-PET cameras and workstations were sometimes different from one centre to another. It therefore seemed important to have a validation cohort showing that differences in SUV measurement (by experienced nuclear medicine physicians) were insignificant and did not impact interpretation of FDG-PET data.

In our series, the intensity of biological myolysis did not correlate with muscle [18F]-FDG uptake. Tanaka et al. had however been able to find a correlation between CPK levels and muscle SUV in a series of 20 patients with IIM by averaging the SUV for proximal muscles bilaterally—a complex and time-consuming feat in daily practice [11]. The clinical value of this finding is questionable since another study (n = 33) did not find a relationship between the same biological parameter and muscle uptake [12]. Unsurprisingly, clinical muscle strength testing and SUV_{PROX} do not correlate.

In normal subjects, there can be a physiological muscle uptake but the latter is nearly always less intense than the SUV_{LIV} [17]. Therefore, it seems logical to use the liver as a region of interest for the studies of SUV, since muscle-to-liver SUV ratios improve measurements dependent on variables such as scanner calibration, tracer dosing, patient weight and body surface [18, 19]. In a retrospective study of 24 cases of

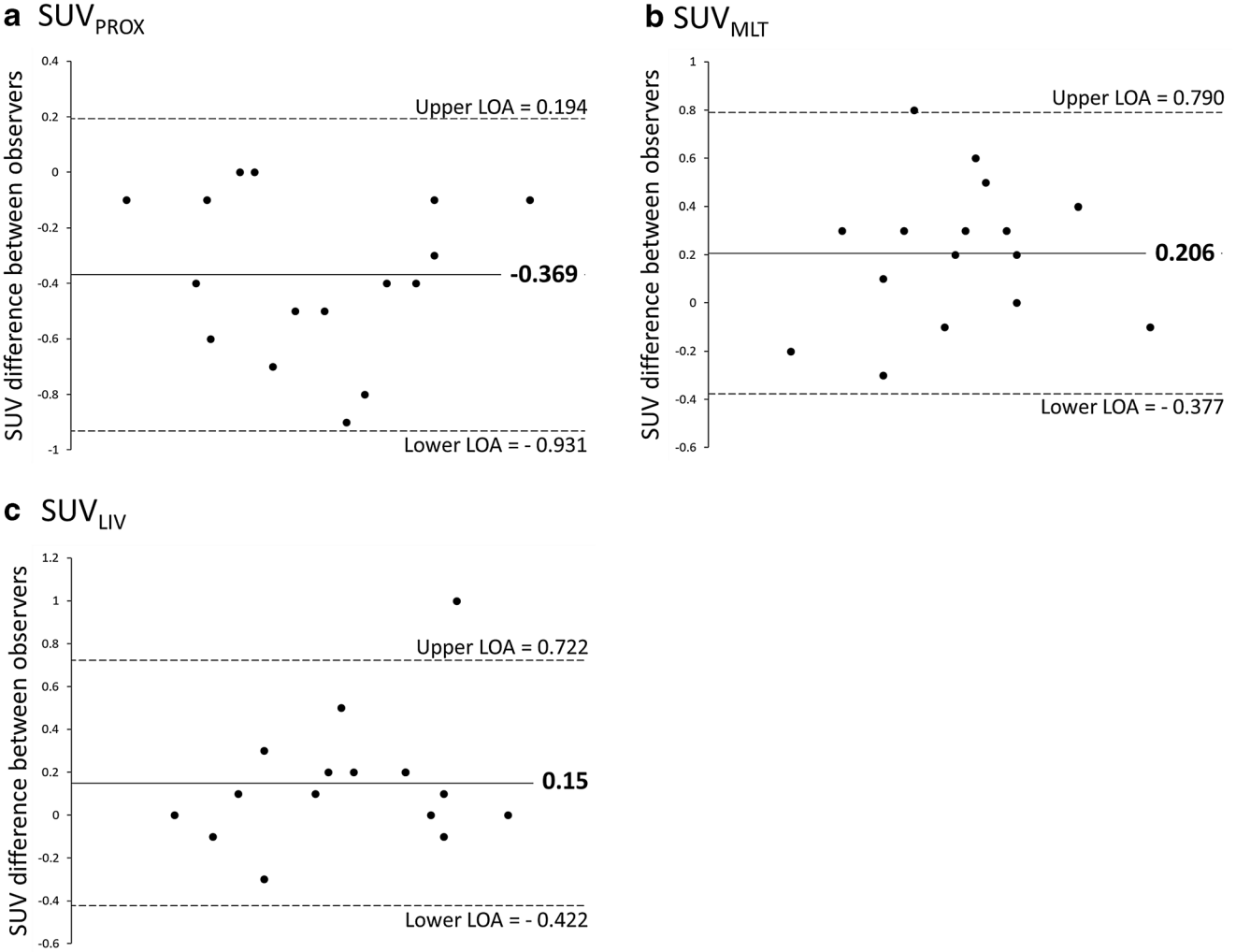

Fig. 3 Bland-Altman plots comparing differences between SUV measurements between two independent observers for 16 patients. The vertical axis represents the calculated difference (in g/mL) between SUV measurements for a given patient—with horizontal solid lines showing calculated biases (values in bold). Upper and lower limits of agreement (LOA) are given (dotted horizontal lines) with a 95% confidence interval. *SUV*, standardised uptake values; SUV_{PROX}, maximal SUV in proximal muscles; SUV_{MLT}, maximal SUV in musculus longissimus thoracis; SUV_{LIV}, mean SUV of the liver

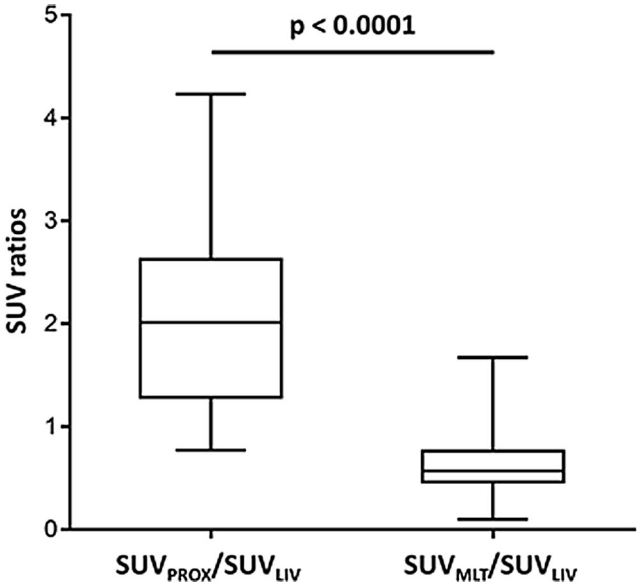

Fig. 4 A comparison of SUV ratios (Wilcoxon signed-rank test). *SUV*, standardised uptake values; SUV_{PROX}, maximal SUV in proximal muscles; SUV_{MLT}, maximal SUV in musculus longissimus thoracis; SUV_{LIV}, mean SUV of the liver

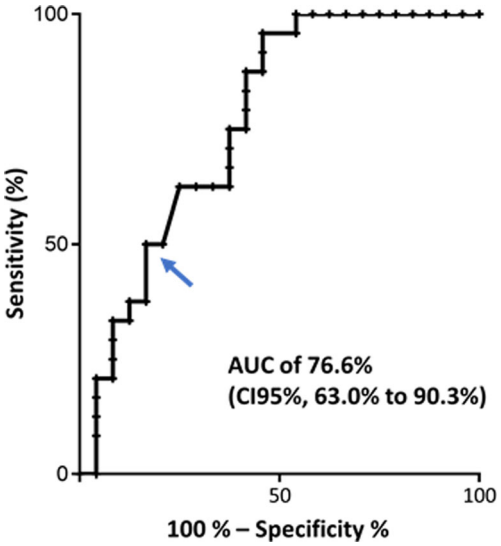

Fig. 6 Receiver operating characteristic (ROC) curve using the SUV_{PROX}/SUV_{MLT} ratio as a classifier. The arrow represents a 1.73 cut-off value with a sensitivity of 50% (CI95%, 29.1 to 70.9%) and specificity of 83.3% (CI95%, 62.6 to 95.3%). SUV_{PROX}, maximal SUV in proximal muscles; SUV_{MLT}, maximal SUV in musculus longissimus thoracis; *AUC*, area under the curve

DM and polymyositis (PM), Owada et al. showed that there was a significant difference in muscle-to-liver SUV in subjects with DM/PM and their controls [9]. The technique was however neither very sensitive nor specific in relation to electromyogram readings and muscle biopsy findings.

The low sensitivity of FDG-PET, in our study, can be explained by the heterogeneity in patient recruitment but also by the possible side effects from immunosuppressive drugs and steroid intake in these very same patients. However, immunosuppressive drugs are not effective before at least 3 weeks whereas the median time to FDG-PET was 15 days for such patients who generally have a more active disease [20]. Such patients were therefore not excluded from the study.

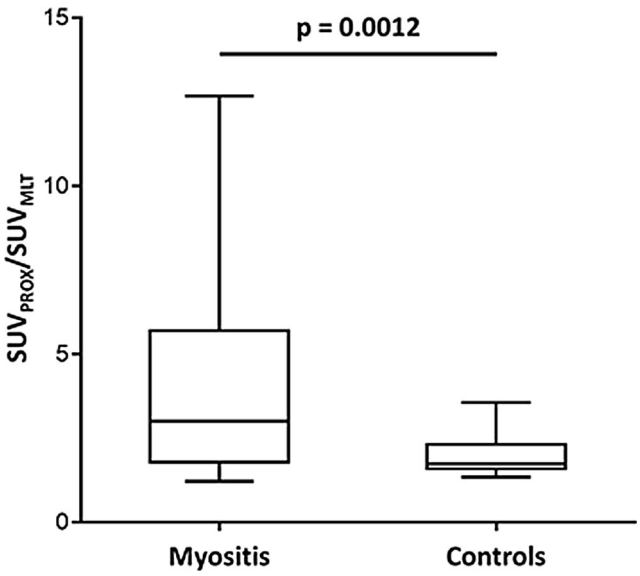

Fig. 5 A comparison of SUV_{PROX}/SUV_{MLT} ratios between dermatomyositis patients (DM) and control subjects (melanoma). SUV_{PROX}, maximal SUV in proximal muscles; SUV_{MLT}, maximal SUV in musculus longissimus thoracis

Unlike cancerous lesions, [18F]-FDG muscle uptake is significantly less intense. Furthermore, SUV_{LIV} can be impacted by interpatient variability, systemic inflammation and/or pharmacological treatment [21, 22]. To avoid such drawbacks in FDG-PET interpretation, other authors suggested using qualitative approaches studying muscle uptake based on that of mediastinum blood vessels—and were able to identify active myositis in around 60% of subjects presenting with IIM [12].

We decided to refine such an approach by studying SUV_{PROX}/SUV_{MLT}. SUV_{MLT} is generally measured at 1 g/mL in subjects with DM, including in cases where biological myolysis is intense, as our data have confirmed. On this basis, we hypothesised that a muscle-to-muscle (SUV_{PROX}/SUV_{MLT}) ratio could define active disease in DM: each patient becoming his/her own control. A 1.73 ratio threshold—over which active IIM should be suspected—was also calculated. Amongst the four patients presenting with amyopathic DM, the only subject to show high muscular SUV (with normal CPK levels) had been treated with hydroxychloroquine. The latter is known to reduce the degradation of insulin and, by that standard, could increase skeletal muscle glucose uptake—and therefore, [18F]-FDG uptake [23–25].

We were able to validate our hypothesis through the comparison of tracer uptake between DM patients and their controls. A SUV_{PROX}/SUV_{MLT} ratio > 1.73 would appear as a

solid diagnostic criterion of active myositis due to its relatively high specificity. This should, of course, be combined with the characteristic symmetrical and proximal patterns of [18F]-FDG muscle uptake in IIM on FDG-PET imaging if it is to have any diagnostic value.

Limitations of our study

Our study has numerous limitations. The first being the small number of subjects due to patient inclusion criteria being perhaps too stringent and the low incidence of the disease. On hindsight, it would have been of interest to include all forms of IIM. Furthermore, our choice of control patients is debatable. Tateyama et al. had decided to select control subjects with a non-inflammatory debilitating muscle disease such as amyotrophic lateral sclerosis [12]. Other authors used subjects with systemic inflammatory non-muscular diseases (i.e. cancer, autoimmune systemic diseases…) as controls [9, 11]. Our choice of control subjects was based on the need to compare DM with patients suffering from an inflammatory process without muscle involvement, but, most of all, with a "full body" scan. Image acquisition and analysis was performed with different equipment and FDG-PET interpretation was not always centralised. Therefore, it was crucial to test and quantify agreement between SUV assessment from two independent physicians blinded to clinical and biological data. Our work suffered, to a lesser extent, from lacking data regarding MSA and MAA—elements that could have allowed better classification of patients. To our regret, MRI data were insufficient to enable us to study its diagnostic value in relation to FDG-PET. We must bear in mind that the latter was mostly prescribed to investigate suspicious radiological lesions.

Practical considerations for the use of SUV_{PROX}/SUV_{MLT} ratio in DM

A proximal and symmetrical [18F]-FDG muscle uptake with a SUV_{PROX}/SUV_{MLT} ratio greater than 1.73 may find its place in patients suspected of having a relapse of their disease. Differentiating active myositis from other causes of muscle weakness (i.e. glucocorticoid-induced myopathy) based on the muscle-uptake pattern seems like an interesting option especially in elderly or comorbid patients. FDG-PET has the added value of identifying other sources of inflammation in patients presenting with a disease that is often associated with neoplastic entities [26, 27]. Our study provides information only on DM, but we believe that this process can be applied to other IIM. In seronegative forms of IIM, the uptake pattern and the SUV ratio might even be of diagnostic value. Unfortunately, as previously mentioned, DM activity does not correlate with muscle SUV.

Conclusion

A muscle-to-muscle SUV_{PROX}/SUV_{MLT} ratio with a threshold of 1.73 can be used in FDG-PET imaging of DM to determine active disease. When associated with a proximal and symmetrical muscle-uptake pattern and clinical findings, it furthermore appears as a potential diagnostic criterion for active DM. Its simplicity and reproducibility make this an interesting method for assessing muscle involvement in DM.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Nihal Martis.

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry One of the authors (Nicolas Mounier) has significant statistical expertise. No complex statistical methods were necessary for this paper.

Ethical approval In accordance with French regulation, approval of the institutional review board was not required but the data were collected, stored and handled anonymously as it is usually the case in retrospective studies.

Informed consent For this type of study, formal patient consent was not required for de-identified data according to French Regulation ("recherche de catégorie 3").

Methodology
- retrospective
- diagnostic study
- multicentre study

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