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LARYNGOLOGY

Thyroarytenoid muscle uptake and attenuation in PET/CT in elderly

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Abstract The objective of this study is to compare uptake and attenuation on positron emission tomography/computed tomography (PET/CT) imaging modality at the thyroarytenoid muscle between subjects aged less and older than 65 years old. The study design is retrospective chart review. The setting is academic medical center. PET/CT images of 60 patients aged less than 65 years old and 60 patients aged more than 65 years old were selected. Demographic data were collected. Both the groups were compared with respect to the maximum standardized uptake value (SUV max) and CT attenuation of bilateral thyroarytenoid muscles. The mean SUV max of the right thyroarytenoid muscle was 2.09 ± 0.8 in the group of patients aged less than 65 years old compared to 1.9 ± 0.6 in the group of patients aged more than 65 years old. For the left thyroarytenoid muscle, the mean SUV max in the first and second groups was, respectively, 2 ± 0.6 and 1.9 ± 0.6. The differences were not statistically significant. As for the CT attenuation, the mean value at the right thyroarytenoid muscle in the first and second groups was, respectively, 31.2 ± 0.8 HU and 20.8 ± 14.4 HU ($p < 0.05$). At the left thyroarytenoid muscle, the mean value was, respectively, 29.6 ± 9.9 and 22.8 ± 15 ($p < 0.05$). This study suggests that CT attenuation measurements can be used for objectively assessing the change in the density of aging thyroarytenoid muscle.

Keywords Aging · Thyroarytenoid muscle · Maximum standardized uptake value · Computed tomographic attenuation

Introduction

Fluorodeoxyglucose F 18 (FDG)-positron emission tomography (PET) is a primary modality of imaging commonly used in staging of head and neck cancers and follow-up after treatment [1].

With the increase in its use in medical daily practice, a physiologic pattern of uptake has been noted at the level of many body structures. The areas mostly subject to an altered physiological uptake are the head and neck, thorax, and upper extremities [2]. More specifically, in the head and neck zones, the scalene, masseter, sternocleidomastoid, and vocal muscles were reported to have an increased physiologic uptake of FDG [2]. To improve the interpretation of the increased uptake seen on PET and to be able to classify it as physiological or pathological, PET has been combined with CT imaging modality. This combination has the benefit of improving spatial resolution, better localizing the different anatomical landmarks and correlating the increased FDG uptake to any morphologic change seen on CT [3].

Since PET measures the metabolic activity of glucose in different types of tissues and since the consistency and volume of tissues change with age, it became interesting to analyze these changes by the PET/CT fusion imaging. Wehrli

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et al. studied the differences in uptake and attenuation at the level of the skin, fat, and skeletal muscles among different age groups. The studied muscles were the psoas, infraspinatus, and subscapularis muscles. Significant changes with age were noted in the maximum standardized uptake value (SUV max) and the attenuation [4]. Mahne et al. studied the changes in FDG uptake with age in the head and neck areas specifically looking at the tongue, soft palate, tonsils, adenoids, the parotid, submandibular, sublingual, palatine, and thyroid glands. A significant difference was found in the volume and in the attenuation of the submandibular glands with age [5]. The authors did not look at any possible difference in uptake and/or attenuation at the level of the vocal cords and no other study in the literature did.

The aim of this study is to compare the uptake and attenuation on the PET/CT imaging modality at the level of the vocal cords, more specifically at the thyroarytenoid muscle, between subjects less than 65 years old and subjects older than 65 years. The age of 65 years was used to separate the two groups based on its common use in defining elderly subjects [6]. The results of this investigation will help physicians a better interpret the laryngeal PET/CT findings in elderly given that thyroarytenoid muscular changes do occur in patients with presbyphonia. The hypothesis is that a difference in uptake and attenuation is present on PET/CT at the level of the thyroarytenoid muscle between the different age groups.

Materials and methods

This is a retrospective study that was approved by the Institutional Review Board at the American University of Beirut. The PET/CT images of 60 adult patients aged less than 65 years and 60 patients aged more than 65 years, performed between February 2015 and February 2016, were randomly selected and reviewed by a well experienced radiologist. All the reviewed radiological examinations were initially requested for the evaluation of patients with malignancies outside the larynx.

The collected demographic data included age and gender. Patients with known history of vocal cord paralysis, laryngeal lesion, history of laryngeal cancer, laryngeal surgery, or prior neck radiation were excluded.

No subjective measures were obtained in this study in view of the retrospective nature of this study.

The patients had undergone PET/CT hybrid imaging using a Philips GEMINI TF scanner following the intravenous administration of 0.1 mCi/kg of F18-fluorodeoxyglucose. At the time of examination, data on age, body weight, and blood glucose levels were collected from the subjects. It is important to note that all patients were required to fast for at least 6 h before imaging and that the fasting glucose levels were within normal ranges. Prior to image acquisition, the patients were allowed to rest quietly for approximately 60 min, as part of the routine protocol. Time of flight image acquisition was performed from the vertex of the skull to ankles, with 4 mm thick image slices in the axial plane. Four millimeter thick CT scanning was performed for attenuation correction, image registration, and diagnosis, with scan parameters optimized to minimize radiation exposure to the patient. Images were fused in the axial plane, and coronal and sagittal reformatted images were also obtained.

The radiologist drew an elliptical region of interest (ROI) measuring 0.5 mm in width and 8 mm in length, oriented parallel to the thyroarytenoid muscles, with the ROI positioned on the mid aspect of the thyroarytenoid muscle on the axial CT images. The average CT density (measured in Hounsfield units) of both the left and right thyroarytenoid muscles in each patient was measured. Similar ROIs were drawn on the fused PET-CT images at the level of the thyroarytenoid muscles to obtain the maximal standard uptake values (SUVmax) at these levels. The SUV measurements were defined as the regional tissue radioactivity concentration normalized for the injected dose and body weight, independent of the fat and muscle contents of the body. Since the CT scan axial slices were 4 mm thick, a number of examinations did not include representative portions of the thyroarytenoid muscles, and these were thus excluded from the study during screening.

Both groups were compared with respect to demographic data and PET/CT findings using non-parametric tests. Differences were considered significant for $p < 0.05$. Further analysis was performed to investigate the association between each radiological outcome measure and age as a continuous variable. The statistical analysis was performed using the SPSS software 22nd edition.

Results

Demographic data

In the group aged less than 65 years old, the mean age was 43.3 years (SD = 12.65) with a range from 23 to 63 years. Twenty-three patients were males and 37 females. In the group aged more or equal to 65 years old, the mean age was 72.01 years (SD = 5.28) with a range from 65 to 87 years. Thirty-two patients were males and 28 were females (Table 1).

PET radiological findings

The mean of SUV max at the level of the right thyroarytenoid muscle was 2.09 ± 0.8 in the group aged less than

Table 1 Demographic data

Variables	<65 years	≥65 years	*p* value
Total sample	$N = 60$	$N = 60$	
Mean age (±SD)	43.3 (±12.65)	72.01 (±5.28)	
Gender			
Male	23 (38.3 %)	32 (53.3 %)	0.10
Female	37 (61.7 %)	28 (46.7 %)	

65 years old, compared to 1.9 ± 0.6 in the group aged more than 65 years old. At the level of the left thyroarytenoid muscle, the means SUV max in the first and second groups were, respectively, 2 ± 0.6 and 1.9 ± 0.6 (see Fig. 1). Despite the decreased FDG-PET uptake between the two groups, the differences were not statistically significant (Table 2). A lack of statistically significant difference was also obtained when looking at the association between FDG-PET uptake and age that was taken as a continuous variable.

CT radiological findings

Comparing the CT attenuation, the mean in Hounsfield unit (HU) of the right thyroarytenoid muscle was 31.2 ± 11.9 for the group aged less than 65 years old and 20.8 ± 14.4 in the group aged more than 65 years old. The difference between the two groups was statistically significant ($p < 0.05$) (see Fig. 2). Similarly, at the level of the left thyroarytenoid muscle, the means in the first and second groups were, respectively, 29.6 ± 9.9 and 22.8 ± 15.0, and the difference was also statistically significant ($p < 0.05$) (Table 3). When looking at the association between CT attenuation and age as a continuous variable, still, there was a significant decrease in thyroarytenoid muscle density that was observed with age ($p < 0.05$).

Discussion

Skeletal muscles are among the organs mostly subject to metabolic changes in response to different physiologic factors. Aging is one of the physiologic factors that, in the fourth decade of life, leads to a decrease in body muscular mass and strength [7–10]. The laryngeal muscles, such as all body skeletal muscles, become less dense with age. The decrease in muscular density is caused by muscular atrophy secondary to its overuse and disuse, as well as changes affecting the neuromuscular junction [11]. With age, a reduction in the axon terminal area and an increase in the unoccupied postsynaptic acetylcholine receptors lead to an irreversible modification of the synaptic architecture [12]. The density of laryngeal muscles is also reduced in elderly secondary to an altered muscular microcirculation. Frontera et al. found a significant decrease in the capillary to fiber ratio with age in skeletal muscles [8]. Furthermore, aging leads to increased amounts of intramuscular lipid deposits [7–10].

Given the aforementioned histopathological muscular changes witnessed with aging, which equally affect the intrinsic laryngeal muscles, one would anticipate a decrease in the attenuation of the thyroarytenoid muscle on computed tomography. In alignment with the hypothesis set by the authors at the start of this manuscript, indeed, the results of this investigation indicate a significant decrease in the mean HU in the elderly subjects compared to those under the age of 65 years. These findings were further substantiated by having similar results on both sides, namely left and right. Our results corroborate the results of the study done by Wehrli et al., in which they had a decrease in CT attenuation with age in all tested skeletal muscles [5]. Measuring the CT attenuation showed that the computed tomographic imaging modality can be used to substantiate the changes affecting the thyroarytenoid

Fig. 1 Axial fused PET/CT images at the level of the vocal cords. **a** 72-year-old woman with right thyroarytenoid muscle measuring MaxSVU of 2.3. **b** 27-year-old man with right thyroarytenoid muscle measuring MAXSVU of 3.5

Table 2 PET uptake measurements at the level of the thyroarytenoid muscles

Variables	<65 years	≥65 years	*p* value
Total sample	$N = 60$	$N = 60$	
SUV max[a] right thyroarytenoid muscle			
Mean (±SD)	2.09 (±0.8)	1.9 (±0.6)	0.25
SUV max[a] left thyroarytenoid muscle			
Mean (±SD)	2.0 (±0.6)	1.9 (±0.6)	0.49

[a] SUV max: maximum standardized uptake value

muscle with aging. Clinically, it can be used to detect early thyroarytenoid muscle atrophy in elderly patients as well as patients having other comorbidities affecting skeletal muscle density.

Surprisingly, despite the significant difference in the attenuation between the elderly group and subjects less than 65 years old, the results of this investigation failed to show a significant difference in the uptake on PET scan between the two groups. Several studies confirm the fact that the uptake of FDG is affected by any change in the metabolic activity among the different tested body structures. An increased uptake is seen in the case of an increased cellular metabolism, such as muscular hyperactivity and inflammatory processes attributed to pathological as well as physiological processes [1]. At the level of the vocal cords, an increased physiologic uptake is frequently seen in conditions, where there is an increase in the muscular volume and/or muscular activity [13, 14]. Any phonatory activity prior to the PET exam has a significant effect on the degree of muscular uptake of the vocal cords [2], for which reason patients are instructed to refrain from talking prior to imaging. On the other hand, a decrease in the uptake has been described in patients with paretic or paralytic vocal cords secondary to the decrease use of glucose by laryngeal muscles on the affected side [15]. Contrarily, an increased uptake is seen at the level of the normal vocal cord due to the compensatory behavior [15].

That being said, we would anticipate a significant decrease in the uptake of the TA muscles in elderly versus those less than 65 years; a difference that would be commensurate with the decrease in muscle mass and activity of the corresponding muscle. The findings of this investigation did not corroborate this hypothesis. This can be attributed on one hand to the variations in the phonatory behavior among subjects, though they are instructed to remain silent prior to examination, and on the other hand, to the possible laryngeal manifestations of numerous systemic diseases, such as diabetes, dyslipidemia, autoimmune, and inflammatory diseases, all of which can markedly affect skeletal muscle metabolic state with possible change in the FDG uptake ion PET scan.

This study is the first to examine the uptake and attenuation of the thyroarytenoid muscle in elderly compared to subjects less than 65 years old. Nevertheless, it carries few limitations: one is the nature of this investigation, namely being retrospective which hinders the ability to inform patients on the need to absolutely refrain from talking prior to the PET examination, a factor that is known to increase the uptake at the level of the thyroarytenoid muscles. Second is the absence of subjective as well as objective voice assessment, which limits the clinical significance of the results of this study. A correlation with the symptomatology and endoscopic findings is needed to draw any possible clinical significance. Third is the lack of information on the phonatory behavior and vocal hygiene status of the investigated subjects in addition to the presence or the absence of systemic disease that may have laryngeal manifestations, such as diabetes, dyslipidemia, and gastroesophageal reflux.

Documenting the decrease in attenuation of the thyroarytenoid muscle with age reflects a decrease in its density and volume, all of which are indicative signs of atrophy. These findings not only substantiate the cause–effect relationship between muscular changes, namely atrophy and dysphonia in elderly, but also allude to a more

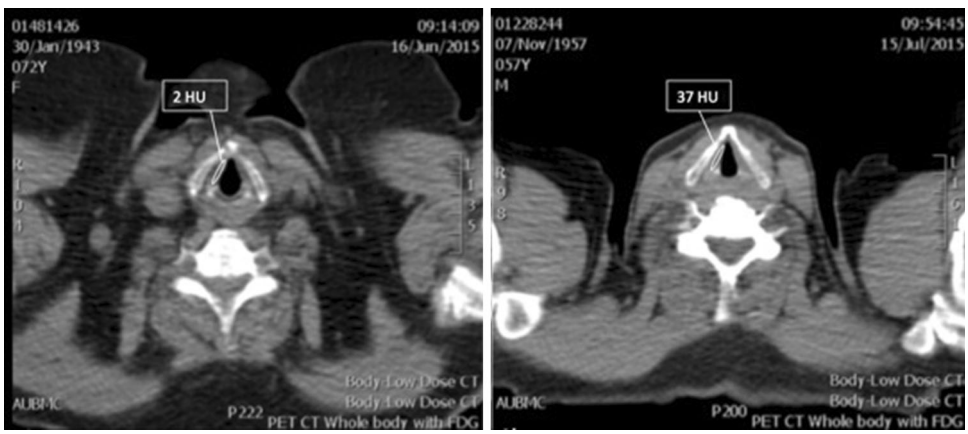

Fig. 2 Axial CT images (level of vocal cords). **a** 72-year-old woman with the right thyroarytenoid muscle measuring an average CT density of two Hounsfield units. **b** 57-year-old man with the right thyroarytenoid muscle measuring 37 Hounsfield units

Table 3 Computed tomographic attenuation measurements at the level of the thyroarytenoid muscles

Variables	<65 years	≥65 years	*p* value
Total sample	$N = 60$	$N = 60$	
Mean HU right thyroarytenoid muscle			
Mean (±SD)	31.2 (±11.9)	20.8 (±14.4)	<0.0001
Mean HU left thyroarytenoid muscle			
Mean (±SD)	29.6 (±9.9)	22.8 (±15.0)	0.004

radical approach in the treatment of presbyphonia when atrophy of the thyoarytenoid muscle is present. A future study grading the extent of attenuation and atrophy, coupled with objective and subjective measures of dysphonia, can help us to draw a framework algorithm on how to approach presbyphonia and when to intervene surgically in addition to voice therapy.

Conclusion

Computed tomographic attenuation measurements can be used as an effective tool for objectively assessing vocal cord muscle density. This is the first study to compare PET/CT results at the level of the vocal cords between patients aged less or more than 65 years old. Larger studies are needed for better evaluating the role of PET/CT in the larynx, where all risk factors affecting skeletal muscles density should be analyzed.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors. For this type of study, formal consent is not required.

References

1. Huang BY, Solle M, Weissler MC (2012) Larynx: anatomic imaging for diagnosis and management. Otolaryng clin N Am 45(6):1325–1361
2. Gupta T, Master Z, Kannan S et al (2011) Diagnostic performance of post-treatment FDG PET or FDG PET/CT imaging in head and neck cancer: a systematic review and meta-analysis. Eur J Nucl Med Mol Imaging 38(11):2083–2095
3. Mahne A, El-Haddad G, Alavi A et al (2007) Assessment of age-related morphological and functional changes of selected structures of the head and neck by computed tomography, magnetic resonance imaging, and positron emission tomography. Semin Nucl Med 37(2):88–102
4. Blodgett TM, Fukui MB, Snyderman CH et al (2005) Combined PET-CT in the head and neck: part 1. Physiologic, altered physiologic, and artifactual FDG uptake. Radiographics 25(4):897–912
5. Wehrli NE, Bural G, Houseni M et al (2007) Determination of age-related changes in structure and function of skin, adipose tissue, and skeletal muscle with computed tomography, magnetic resonance imaging, and positron emission tomography. Semin Nucl Med 37(3):195–205
6. World Health Organization (2010) Definition of an older or elderly person. WHO, Geneva, Switzerland http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html. Accessed 12 Nov 2013
7. Kirkeby S, Garbarsch C (2000) Aging affects different human muscles in various ways. An image analysis of the histomorphometric characteristics of fiber types in human masseter and vastus lateralis muscles from young adults and the very old. Histol Histopathol 15(1):61–71
8. Frontera WR, Hughes VA, Fielding RA et al (1985) Aging of skeletal muscle: a 12-yr longitudinal study. J Appl Physiol 2000 88(4):1321–1326
9. Payne GW, Bearden SE (2006) The microcirculation of skeletal muscle in aging. Microcirculation 13:275–277
10. Nair KS (2005) Aging muscle. Am J Clin Nutr 81:953–963
11. Lynch NA, Metter EJ, Lindle RS, Fozard JL et al (1999) Muscle quality. Age-associated differences between arm and leg muscle groups. J Appl Physiol 86:188–194
12. Thomas LB, Harrison AL, Stemple JC (2008) Aging thyroarytenoid and limb skeletal muscle: lessons in contrast. J Voice 22(4):430–450
13. Nakamoto Y, Tatsumi M, Hammoud D et al (2005) Normal FDG distribution patterns in the head and neck: PET/CT evaluation. Radiology 234(3):879–888
14. Reinking MF, Osman MM (2009) Prospective evaluation of physiologic uptake detected with true whole-body 18F-FDG PET/CT in healthy subjects. J Nucl Med Technol 37(1):31–37
15. Komissarova M, Wong KK, Piert M et al (2009) Spectrum of 18F-FDG PET/CT findings in oncology-related recurrent laryngeal nerve palsy. AJR 192(1):288–294