Review of Brown Adipose Tissue/Beige Fat Cell Cases Diagnosed by FDG PET at Our Institution

Tsuyoshi Yoshida, M.D.,Ph.D. and Masayuki Sasaki, M.D.,Ph.D. PET Imaging Center, Koga Hospital 21, Kurume, Fukuoka, Japan

Introduction

Adipocytes include brown adipocytes, beige adipocytes, and white adipocytes(Table 1). In adult humans, brown adipose tissue (BAT) is primarily composed of beige adipocytes . The differentiation of beige adipocytes (browning) is induced by stimuli such as exposure to cold environments or administration of certain antidiabetic drugs, and they disappear when the stimulus is removed.

Table 1 Localization and characteristics of brown, beige and white adipocytes

	Brown Adipocytes	Beige Adipocytes	White Adipocytes
Main Anatomical Location	Interscapular, axillary, perirenal (mouse) Interscapular, perirenal (human, infants)	Subcutaneous adipose tissue in cervical & inguinal regions (mouse) Supraclavicular, paravertebral, cervical, axillary (human adults)	Subcutaneous and visceral adipose tissue throughout the body (mouse, human)
Cell Lineage/Origin	Myogenic progenitors	Adipogenic progenitors	Adipogenic progenitors
State of Existence	Constitutive	Inducible	Constitutive
Morphological Features	Multilocular lipid droplets, abundant mitochondria	Multilocular lipid droplets, abundant mitochondria	Unilocular lipid droplets, scanty cytoplasm
Physiological Function	Energy expenditure (metabolic thermogenesis)	Energy expenditure (metabolic thermogenesis)	Energy storage and release, secretion of adipokines

※Modified from: Yoneshiro, T. & Kajimura, S. Regulatory Mechanisms and Clinical Implications of Brown and Beige Adipocytes (in Japanese). Journal of Japanese Biochemical Society 89(6): 917-920 (2017)

In humans, BAT is found in locations such as the interscapular region, perirenal region,supraclavicular fossa, axillary region, and paravertebral region(Figure 1).

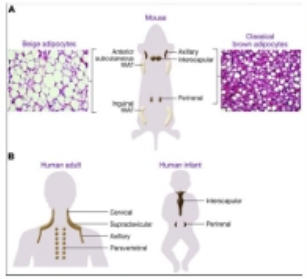

Figure 1. Anatomical locations of thermogenic adipocytes in mice and human.

(A) In rodents, interscapular BAT and perirenal BAT are composed of classical brown adipocytes. Beige adipocytes are largely found in subcutaneous white adipose tissue(WAT) (anterior and inguinal WAT) and are highly recruitable (a process referred to as "browning" of WAT) by certain external cues.

(B) Adult human BAT is located mainly in the cervical, supraclavicular, and paravertebral regions. In infants, BAT is found in the interscapular and perirenal regions.

※From review article: Sidossis, L, Kajimura, S. Brown and beige fat in humans: thermogenic adipocytes that control energy and glucose homeostasis. J Clin Invest.2015;125(2):478-486.

Purpose

This study reviews the distribution of BAT/Beige Fat Cell(BFC) cases observed in FDG PET/CT examinees (malignant and non-malignant) at our institution.

Material and method

This retrospective study was approved by our social medical corporation's Reserch Ethics Review Committee (approval number: Gaku-25-0057) and the authors have no COI to disclose. All patients who underwent FDG PET/CT at our institution between December 2009 and December 2025 were included in this study. 154 cases were diagnosed with BAT/BFC (83 malignant, 71 non-malignant). Each patient fasted for over 4 h before FDG administration. Oral diabetic medications and insulin shots were discontinued the day before FDG administration. Patient received 3.7 MBq (0.0001 Ci)/kg of FDG. PET/ CT imaging was performed 60 min after FDG injection using a PET/CT system (Biograph True Point 16/40, Siemens Healthineers, Erlangen, Germany). Following low-dose CT, PET was conducted for 20 min.

BAT was evaluated using fused PET/CT images by two Nuclear medicine specialists with over 20 years of clinical experience. We classifed the BAT distribution patterns according to classification by Toyama et al.. First, cases with positive accumulation in the supraclavicular or axillary region were classified as T-type. These patients often exhibited concurrent accumulation in the paravertebral region, forming a T-shape on maximum intensity projection (MIP) images. Second, cases with positive accumulation in the cervical or paravertebral region without supraclavicular or axillary involvement were classified as I-type. Third, cases with positive accumulation localized to the lipomatous hypertrophy of the interatrial septum (LHIS) were classified as the LHIS-type (Figure 2). Regardless of thickness, cases in the interatrial septum region were considered LHIS-positive. The presence or absence of LHIS accumulation did not affect the classification of T- and I-types. Finally, cases not meeting any of these classifications were categorized as O"ther"-type. Distributions were compared by age (<60 vs. ≥60 years) and malignancy status.

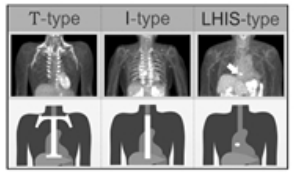

Figure 2.

BAT distribution patterns on MIP and fusion image were classified into three types: T-type (positive accumulation in the supraclavicular or axially regions), I-type (positive accumulation in the cervical or paravertebral region without supraclavicular or axially involvement), and LHIS-type (positive accumulation localized solely to LHIS)

※From: Toyama et al. Distribution patterns of brown adipose tissue on FDG-PET/CT has age characteristics. Annals of Nuclear Medicine (2025) 39:1291–1296

Result

Manthly cases by age group and distribution type were shown in the Figure 3. We believe this indicates the expression of BAT in response to cold stimulation.

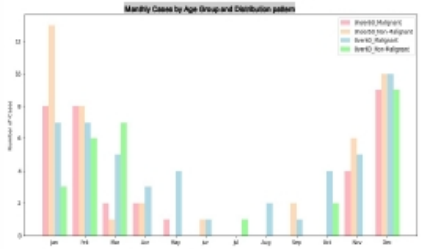

Figure 3.

Manthly cases by age group and distribution pattern

The distribution of BAT patterns was as follows:

In patients <60 years: malignant group T-type 24, I-type 10, LHIS-type 0, O-type 0
non-malignant group T-type 31, I-type 11, LHIS-type 0, O-type 1
In patients ≥60 years: malignant group T-type 9, I-type 16, LHIS-type 20, O-type 4
non-malignant group T-type 14, I-type 11, LHIS-type 3, O-type 0

In patients <60 years, T-type (Figure 4.) predominated in both malignant (24/34) and non-malignant (31/43) groups. In patients ≥60 years, atypical distributions (LHIS and Others (Figure 5.)) were more frequent in the malignant group (24/49) compared with those <60 years (0/34) (Fisher's exact test, p<0.0001)(Table 3) . No significant age-related differences were observed in the non-malignant group.

Table 3. Fisher's exact test, *p<0.0001

Age Group	Typical (T & I)	Atypical (LHIS & O)	Total
Under 60	34 + 42 = 76	0 + 1 = 1	77
60 and Over	25 + 25 = 50	24 + 3 = 27*	77
Total	126	28	154

In the Others category, rare sites included the orbit (n=2)(Figure 6.), lower dorsal esophagus (n=1), dorsal pancreas head (n=1), and perirenal area (n=1).

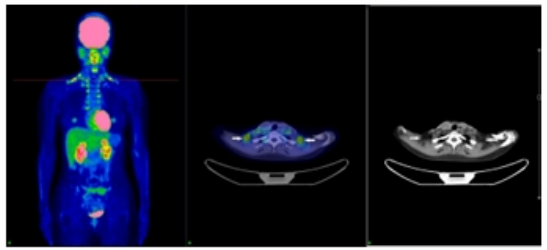

Figure 4.

T-type: 40s Female undergoing PET cancer screening SUVmax=4.92

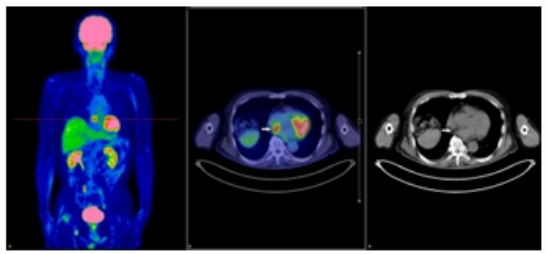

Figure 5.

LHIS-type: 70s Male post-pancreas cancer patient SUVmax=6.28

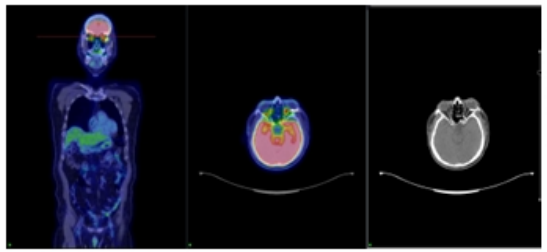

Figure 6.

O-type: 60s Male post-prostate cancer patient SUVmax=6.15

※Note that the FDG accumulation in the left orbit is located within the adipose tissue, separate from the optic nerve bundle and extraocular muscles.

Discussion

In the review by Sidossis et al. on the browning of white adipocytes, in addition to environmental factors such as cold exposure and exercise, the involvement of cancer cachexia and endocrine hormones is also mentioned. In the present results, the distribution of BAT to atypical sites observed in malignant cases aged 60 years and older may reflect the influence of the latter factors. The presence of orbital brown adipose tissue, newly identified in this study, may also be explained by the mechanism of browning of white adipocytes described above.

Conclusion

In malignant cases, patients aged ≥60 years showed a significantly higher frequency of atypical BAT/BFC distributions, particularly LHIS and rare sites. Orbital involvement was identified in two cases and has not been previously reported.