Abnormally increased uptake of 18F-FDG in the forearm and hand following intra-arterial injection — hot forearm and hot hand signs

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ABSTRACT. The aim of this study is to describe the appearance of intra-arterial administration of 18F-fluorodeoxyglucose (18F-FDG). The effect of this finding on the standard uptake values (SUVs) is also briefly discussed. Three cases of 18F-FDG positron emission tomography (PET) scans, detected over 2 years (2004–2006), with different presentations producing hot forearm and hot hand signs are described. It was shown that intra-arterial injections of 18F-FDG producing “the hot forearm sign” and the hot hand sign” are similar to the glove pattern of uptake noted following intra-arterial administration of technetium-99m methylene diphosphonate. Following intra-arterial injection, uptake of 18F-FDG is accentuated by hypoxia and exercise. A comparison is also made with the pattern of soft-tissue uptake seen following true intravenous injections with similar pre-injection vein enhancement techniques to the intra-arterial injections. Evaluation of the maximum intensity projection (MIP) and transaxial PET/CT fusion images of the arm, forearm and hand helps to confirm the diagnosis. Hands are often not included in PET/CT imaging and therefore cases might be missed. In conclusion, intra-arterial injection of 18F-FDG produces a “hot forearm sign” and “hot hand sign”. Hands are often not included in PET/CT imaging, and therefore the presence of hot forearm sign should suggest further investigation. It should be mentioned in the radiology report, as it may alter the sensitivity and specificity of the SUV value.

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Inadvertent intra-arterial injections of various radiopharmaceuticals are well known. A bone imaging agent, such as technetium-99m ($^{99}\text{Tc}^{\text{m}}$) methylene diphosphonate (MDP), when injected into the artery at the antecubital fossa or wrist results in a “glove phenomenon” or “glove-like pattern” of distribution of radioactivity [1–4]. Here, the intra-arterial injection of 18F-fluorodeoxyglucose (18F-FDG) and its uptake in the tissues distal to the injection are described.

Methods and materials

Three cases of 18F-FDG positron emission tomography (PET) scans, performed over 2 years (2004–2006), with hot forearm and hot hand signs are described. All patients had difficult antecubital vein identification that required application of a light rubber tourniquet in the upper arm followed by hand exercises consisting of opening and closing the fist and squeezing a sponge ball several times. Injections were made by different technicians.

Case 1

A 54-year-old man with lung cancer and abnormal liver function tests was referred for a staging 18F-FDG

PET/CT scan. He received 15.6 mCi of 18F-FDG through a pre-placed intravenous canula in the left antecubital region. This was followed by 20–30 ml of saline flush. A 0.9% saline drip was connected thereafter and PET/CT scanning was performed 60 min later after he had rested in a quite dark room during the uptake period. The patient raised his hands above his head, as per the standard protocol during scanning, so that the area of the upper limbs distal to the wrists was not included in the images. Transaxial images of the arm confirmed that the injection was into the brachial artery, and not the antecubital vein as anticipated (Figure 1).

Case 2

A 23-year-old woman with nodular Hodgkin's lymphoma was referred for a post-chemotherapy 18F-FDG PET/CT scan to determine response to therapy. She received 14.1 mCi of 18F-FDG into the right antecubital fossa vein through a pre-placed butterfly needle. 20–30 ml of saline flush was used before and after the FDG injection. A 0.9% saline drip was connected thereafter and PET/CT scanning was performed 50 min later after she had rested quietly in a dark room. She was imaged with her hands crossed over her head, as per the standard protocol during imaging, hence both hands were included into the images. Images revealed that the injection was made into the ulnar artery in the forearm, as the entire artery was clearly identified in the forearm.

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Figure 1. (a) A 54-year-old man with lung cancer and abnormal liver function tests. Image showing the distribution of 18F-fluorodeoxyglucose in the left arm and forearm. (b) Transaxial positron emission tomography/CT fusion images of the arm clearly showing the brachial artery against the humerus.

In the palm, the hypothenar eminence was seen prominently retaining the 18F-FDG dose (Figure 2).

Case 3

A 52-year-old man with oesophageal carcinoma was referred for a 18F-FDG PET/CT scan for staging. He received 16.4 mCi of 18F-FDG in the supposed left antecubital vein through a pre-placed butterfly needle. 20–30 ml of saline flush was used before and after the

injection. Following dose administration, a 0.9% saline drip was administered. The PET/CT scanning was performed 60 min later after the patient had been kept in a dark room during the resting period. He was unable to raise his hands above his head owing to shoulder discomfort and so kept his hands by his side. Thus, the whole of the upper limbs, including both hands, were included in the field of view. It is evident that the injection was made into the ulnar artery, as it can be defined clearly in the forearm with retention of 18F-FDG seen predominantly in the hypothenar eminence of the

Figure 2. (a) A 23-year-old woman with nodular Hodgkin's lymphoma. Image showing the distribution of 18F-fluorodeoxyglucose in the left forearm and hand. (b) Transaxial positron emission tomography (PET)/CT fusion image of the left forearm showing the hypermetabolic ulnar artery against the ulna. (c) Transaxial PET/CT fusion image of the hands showing hypermetabolic left hypothenar eminence.

Figure 3. (a,b) A 52-year-old man with oesophageal carcinoma. Image showing the distribution of ^{18}F -fluorodeoxyglucose in the left forearm and hand. BA, brachial artery; UA, ulnar artery; RA, radial artery. Of note, the low-grade abnormal uptake proximal to the injection site in the brachial artery is probably a result of pulsations (muscular pulsatile activity) of the brachial artery. (c) Transaxial positron emission tomography (PET)/CT fusion image of the left forearm showing the hypermetabolic ulnar artery against the ulna. (d) Transaxial PET/CT fusion image of the proximal portion of the left hand at the level of the trochanter showing hypermetabolic left hypothenar eminence muscles. (e) Transaxial PET/CT fusion image of the distal portion of the left hand at the level of the shaft of the femur showing hypermetabolic left hypothenar and thenar eminence and interossei muscles.

hand. The thenar and interossei groups of muscles also showed hypermetabolism owing to free ulnar–radial communication in the hand (Figure 3).

Results

Intra-arterial injection of ^{18}F -FDG producing a “hot forearm sign” and “hot hand sign” is similar to the glove pattern of uptake described following intra-arterial administration of $^{99}\text{Tc}^{\text{m}}$ MDP. Following intra-arterial injection, uptake of ^{18}F -FDG is accentuated by hypoxia and exercise. Evaluation of MIP and transaxial PET/CT fusion images of the arm, forearm and hand helps to confirm the diagnosis. The hands were included in two out of three cases described here, and this allowed the diagnosis to be made easily. In the case where hands were not included in the field of view, the pattern of distribution of hypermetabolic activity within the major arterial system of the forearm was verified by the transaxial PET/CT fused images, and these helped in making the diagnosis.

Discussion

A retrospective review of three patients revealed that FDG administration was made erroneously, *i.e.* intra-arterially rather than intravenously. This was confirmed by well-defined arteries in the arm and forearm. Application of the tourniquet accentuated the vessels, probably owing to the relative ischaemia/hypoxia, with subsequent transient hyperaemia resulting from the

physiological vasodilatation. It is important to release the tourniquet and wait for at least 1 min before injecting the radiopharmaceutical, as recommended for bone scanning [5]; this technique should be followed for ^{18}F -FDG.

Exercise of the hand is used to make the vessels more prominent by promoting the venous return. However, it not only increases the blood flow but also alters the metabolic state of the muscles of the arm, forearm and hand. It has been shown that the muscles tend to accumulate ^{18}F -FDG during the first pass of an intra-arterial injection. Extraction of ^{18}F -FDG in the first pass is approximately 10% in resting muscles. This extraction is greater after exercise. The tourniquet produces relative transient ischaemia distally in the limb. Anaerobic metabolism is less efficient than aerobic metabolism and, in the state of transient relative hypoxia, the extracted ^{18}F -FDG is retained in the tissues for a relatively longer period [6]. This causes the muscles of the dilated arterial walls and small muscles of the hand (thenar eminence, hypothenar eminence and interossei) to appear hypermetabolic. Intra-arterial injections thus produce a prominent delineation of the arteries of the forearm causing a “hot forearm sign”. As the radial and ulnar arteries in the hand freely communicate with each other through the various palmar and digital arches, there is considerable uptake in the small muscles of the hand, producing a “hot hand sign”. FDG uptake is accentuated by hypoxia and exercise [7–9].

When a true intravenous injection is given in the hand, ^{18}F -FDG gets diluted in its passage through the heart; by

Figure 4. (a) Image showing mildly increased distribution of 18F-fluorodeoxyglucose (18F-FDG) in the left arm (biceps), both forearms and hands following intravenous injection. The first attempt at injection was made in the right upper limb by applying a rubber tourniquet in the right arm and asking the patient to open and close their right fist several times; following a few unsuccessful attempts, the same manoeuvre was repeated on the left side along with a few flexions and extensions of the elbow, with success. This is not an intra-arterial injection. (b) Transaxial image of the body with both forearms showing mildly increased uptake of 18F-FDG in the muscles of both forearms. (c) Transaxial image of the body with both hands showing mildly increased uptake of 18F-FDG in the muscles of both hands.

the time it reaches the arm, forearm and hand, the component of ischaemia and hypoxia is resolved/eliminated to a great extent, and therefore the muscles do not exhibit such intense hypermetabolic activity (Figure 4).

The term "hot hand" has been used in several disciplines ranging from gambling, statistics and economics to basket ball. However, in nuclear medicine, it has a different meaning. The hot forearm or hot hand sign should not be confused with urinary contamination that occurs following administration of iodine-131 for thyroid cancer [10] or as a result of dose infiltration. In the hot forearm sign and hot hand sign, the pattern of distribution of hypermetabolic activity following intra-arterial injection of 18F-FDG is confined to well-defined anatomical regions, and not to haphazard ill-defined patterns noted in other clinical situations. The hot hand sign has also been described in frostbite injuries [11], but the pattern of 18F-FDG appearance in frostbite has not yet been described. Hands are often not included in the PET/CT field of view and it is possible that several cases may go unrecognised. The presence of a hot forearm should alert the reading physician of the possibility of intra-arterial administration of FDG. MIP rotating images and transaxial PET/CT fusion images should be evaluated thoroughly before commenting on intra-arterial administration and, if confirmed, it should be mentioned in the report.

The primary reason for increased forearm/hand uptake in these cases is the arterial injection itself; hypoxia and exercise played minor roles. Therefore, the discussion should not be misleading to the readers. The phenomenon of "hot forearm and hot hand" would occur in inadvertent arterial injections without muscle exercise/ischaemia. Muscle exercise/ischaemia further enhances this pattern of uptake but the extent of enhancement is variable and uncertain at this stage.

Despite the considerable retention of FDG in the forearm and hand, the images were still able to provide the diagnosis. Quantitation of FDG uptake with standard

uptake value (SUV) determination is an important component of 18F-FDG PET imaging. In cases of extravasation of 18F-FDG at the site of administration, the sensitivity and specificity of the SUV is altered [12, 13]. Similar considerations probably occur with intra-arterial injection of 18F-FDG and need to be considered when reporting these values once intra-arterial administration has occurred. Further investigation of this is warranted.

Conclusions

This is the first documented report of three patients receiving intra-arterial administration of 18F-FDG inadvertently. Intra-arterial injection of 18F-FDG produces a "hot forearm sign" and "hot hand sign". As the hands are often not included in PET/CT imaging, presence of the hot forearm sign should alert the imager to this possibility and be adequate to make the diagnosis. It should be mentioned in the report, as it may alter the sensitivity and specificity of the SUV.

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