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Original

Patterns of vascular graft infection in 18F-FDG PET/CT

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Abstract

BACKGROUND: 18F-FDG PET/CT has become an important tool in diagnosis of prosthetic vascular graft infections (PVGI). The aim of the study was to identify the patterns of vascular graft infection in 18F-FDG PET/CT.

MATERIAL AND METHODS: The study was performed in 24 patients with vascular graft infection, in 17 patients implanted in an open surgery mode and in 7 patients by endovascular aortic repair (EVAR). Vascular prostheses were evaluated by two visual scales and semi-quantitative analysis with maximum standardized uptake values (SUV max).

RESULTS: In the 3-point scale: 23 patients were in grade 1 and one patient was in grade 2. In the 5-point scale: 19 patients were in grade 5 with the highest activity in the focal area, 4 patients were in grade 4 and one patient in grade 3. The visual evaluation of 18F-FDG PET/CT study revealed that peri-graft high metabolic activity was associated with occurrence of morphological abnormalities (n = 21) like gas bubbles and peri-graft fluid retention or without abnormal CT findings (n = 3). The presence of the gas bubbles was linked to higher uptake of 18F-FDG ($p < 0.01$, SUVmax 11.81 ± 4.35 vs 7.36 ± 2.80, 15 vs 9 pts). In EVAR procedure, the highest metabolic activity was greater than in classical prosthesis (SUVmax 21.5 vs 13).

CONCLUSIONS: 18F-FDG PET/CT is a very useful tool for assessment of vascular graft infections. CT findings like gas bubbles, or peri-graft fluid retention were associated with significantly higher glucose metabolism; however, in some cases without anatomic alterations, increased metabolic activity was the only sign of infection.

KEY words: fluorodeoxyglucose; PET/CT scan; vascular graft infections

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Introduction

The incidence of prosthetic vascular graft infections (PVGI) is ranging between 1 and 6%, depending on the location of the vascular graft — in intra-abdominal prostheses, the overall risk of infections is around 1%, but considerably increases to 6% when the graft is anastomosed to a femoral artery [1–3]. In 20–75% of cases PVGI may lead to the death, while in 50% it may result in morbidity such as loss of a limb [1, 4]. Regarding the onset of PVGI, there are early and late infections. The early PVGI starts at the time of surgery, when causative organisms infect the graft and may appear up to 4 months after surgery, whereas the more common type — the late one, occurs at least 4 months after the implantation of prosthesis. In the early infections the clinical manifestations of PVGI can be acute, whereas in the late one, may be more subtle. The clinical presentation of the PVGI also depends on the location of the graft. In deeply fashioned grafts, pathology can be faint and difficult to diagnose. In cases of shallow grafts, for example in an extremity, the manifestations are often overt [4].

There are three groups of predisposing risk factor: patient-related, procedure-related and pathogen-related. The patient-related aspects, among others, include: obesity, diabetes, immunodeficiency, infection at the time of graft placement, and prolonged preoperative hospital stay [5, 6]. The procedure-related factors connected with surgery are: prolonged, emergency or "redo" vascular surgery, bowel injury, groin incision, wound infections, postoperative hematoma, seroma, pseudoaneurysm or wound-bed bleeding [5–7]. The causative pathogens are *Staphylococcus aureus* and *Pseudomonas aeruginosa* in 80% of cases, which produce a very strong biofilm, and when they adhere to the graft, infections can easily develop along the prosthesis and adjacent tissue. The pathogens also release destructive endotoxins, which can cause anastomotic dehiscence [6]. Synthetic vascular graft prostheses are made of either polyester (Dacron®) or polytetrafluoroethylene (PTFE), both of which are also used in endovascular and open mode surgery. The incidence of PVGI is comparable in both materials [7].

The right diagnosis of PVGI is crucial, but there is no clear consensus of diagnostics criteria. The imaging of PVGI is still

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challenging, because false-positive tests may lead to unnecessary surgery, whereas false-negative are associated with under-treatment and in consequence with high morbidity [4]. Routine tests in PVGI include: clinical, biochemical, microbiological and imaging studies. Laboratory analysis in prosthesis infection commonly reveal elevated white blood cell (WBC) count, increased C-reactive protein (CRP) serum level and increased sedimentation rate. Microbiological assessment is based on skin, wound, blood or graft surrounding tissue culture. An ultrasound scan can easily detect peri-graft fluid. In contrast enhanced computed tomographic angiography (CECT), which is considered as the test of choice, the manifestation of infection is peri-graft ectopic gas, fluid and soft tissue enhancement and formation of the pseudoaneurysm. In advanced PVGI the detection rate in CECT is close 100%. Morphologic abnormalities are often nonspecific in vascular graft infection, therefore the use of metabolic study increases. The positron emission tomography/computed tomography (PET/CT) with use of 18F-fluoro-2-deoxy-D-glucose (18F-FDG) has become an important method of diagnosing inflammation and infection. In early and low-grade PVGI, the utility of 18F-FDG PET/CT is increased. There are different grades of focal pattern of 18F-FDG uptake.

In the recommendation of Management of Aortic Graft Infection Collaboration (MAGIC) there are three main categories of diagnosis of graft infection: clinical/surgical, radiological and laboratory [8]. Diagnostic criteria were ranked as either "major" or "minor" within each category. As it is recommended in MAGIC, Aortic Graft Infection (AGI) is suspected if one isolated major criterion or two of minor criteria from different categories are present. AGI is confirmed if there is one major plus any other criterion (major or minor) from another category. The major clinical/surgical criteria include presence of pus, open wound, fistula development, graft insertion in infected site. The laboratory major criteria are pathogens recovered from explanted graft or intra-operative or from percutaneous aspirate of peri-graft fluid. The serum levels of inflammatory markers like erythrocyte sedimentation rate (ESR), CRP or WBC belong to the minor criteria in laboratory categories in MAGIC. Major radiological criteria on CT scan are peri-graft fluid more than 3 months or peri-graft gas more than 7 week after prosthesis insertion or increased peri-graft gas in serial imaging. Increased metabolic activity on 18F-FDG PET/CT belongs to minor radiological criteria of infections. In our opinion however, there is much more potential value in non-invasive examination like 18F-FDG PET/CT. There are a number of questions and concerns regarding the diagnosis of vascular prosthesis infections by 18F-FDG PET/CT, but the most important issue is finding the pattern of infection.

The aim of the study was to identify the pattern of aortic vascular graft infection in patients with high probability of infective process by us of 18F-FDG PET/CT.

Material and methods

Patients

The study was performed in 24 consecutive patients who attended Department of Nuclear Medicine University Hospital in Lublin, between March 2013 and October 2018, with vascular graft infection. Clinical material consisted of 21 male and 3 female patients, mean age 65 (35–84) years. Strong clinical suspicion of vascular graft infection was the start point of diagnosis. The definition of vascular prosthesis infection is graft colonization by pathological bacterial strains. According to mentioned above MAGIC criteria [8], the surgical manifestations were: fistula development, infected pseudoaneurysm, erythema, warmth, swelling purulent discharge and pain. Than the laboratory tests, bacterial culture and radiological signs of infection like: peri-graft air, persistent fluid or abscess was noticed in these patients. The main reason of vascular prosthesis implantation was aneurysm of the aorta (19 patients) and Leriche's syndrome (5 patients). In general, there were 4 patients with a thoracic aorta graft (TAG) and 20 patients with an abdominal aorta graft (AAG). In 7 patients endovascular aortic repair (EVAR) was performed: in one patient in the thoracic aorta and in 6 patients in the abdominal aorta. In 17 patients an open surgery mode was applied. In 4 patients the femoro-popliteal graft coexisted (in patients with classical abdominal prostheses). 18F-FDG PET/CT were performed from 12 months to 15 years after vascular graft implantation with the exception of one patient, when 18F-FDG PET/CT was performed 1 month after Bentall de Bono procedure, because of rapid progress of infection symptoms. There were 3 patients with diabetes mellitus in the group of stent-grafts patients. The blood serum inflammatory markers were: CRP mean 80.5 mg/L (range 9–300) and WBC mean 13.4 (range 7–38) K/mL. Baseline study population is presented in Table 1.

Table 1. Description of the study material

Patient's details		Localization of prosthesis	
	n	Thoracic aortic graft	Abdominal aortic graft
All	24	4	20
Age	24	48.8 years	60.3 years
Male	21	4	17
Female	3	0	3
EVAR	7	1	6
Open mode	17	3	14
Coexistence of femoral-popliteal	4	0	4
Diabetes mellitus	3	0	3
Smoking	17	3	14

EVAR — endovascular aortic repair

18F-FDG PET/CT imaging

Patients were prepared for the study with 24 hours of low carbohydrate diet, and fast for at least 6 hours prior to the examination. The interval between insulin and 18F-FDG administration was more than 6 hours. Blood glucose level was measured just before injection and the mean value was 104.7 mg/dL, range was 78–140 mg/dL. One hour before imaging, the subjects were injected with 3.5 MBq of 18F-FDG per kilogram of body weight, mean activity 241.5 MBq, range 198–334 MBq. During the uptake phase, patients were waiting in a quiet, dimly lit room. Patients were scanned in supine position, with arms overhead. 18F-FDG PET/CT scans were obtained from the vertex of skull to the mid-thigh level using 18F-FDG PET/CT system Biograph mCT S(64)-4R (Siemens, Erlangen, Germany).

PET data were collected in a three-dimensional mode, in the caudocranial direction with 2.5 minutes per bed position, and reconstructed with applied absorption and scatter correction. The reconstruction method was the following: True X+ time-of-flight (TOF) and ultra-high-resolution PET technology, 2 iterations, 21 subsets, Gaussian filter full width at half maximum 2.0 mm, image size 200 × 200 (matrix), zoom 1.0 and slice 3 mm. CT was performed prior to PET, without contrast enhancement, using the following parameters: voltage 120 kV, tube current 50, 150 or 200 mAs, pitch 0.8, and slice thickness 3 mm.

Image analysis

All 18F-FDG PET/CT studies were independently assessed by a consensus of two experienced nuclear medicine physicians. Images were evaluated visually and semiquantitatively on a dedicated workstation equipped with fusion software (Syngo Via VA30A, Siemens, Erlangen, Germany), which displays PET, CT, and PET/CT fused images.

Vascular prostheses were evaluated visually, with two visual scales applied [9, 10]. The first one, a three-point scale, with 18F-FDG uptake patterns scored as follows: 1. focal dominant area of 18F-FDG uptake; 2. inhomogeneous or patched and 3. diffused or homogenous [9]. According to published recommendation, the first two were recognized as PVGI [9]. Second visual scale was also utilized. It was a 5-point scale described by Sah et al. [10] where 18F-FDG uptake patterns and CT information were taken into account. In this scale grade 1, 18F-FDG uptake in vascular graft was normal as in background activity; grade 2, mild increased but diffused along the graft; grade 3, focal, but mild uptake or strongly diffused; grade 4, focal and intense (and diffused 18F-FDG uptake along the graft); grade 5, focal and intense 18F-FDG uptake plus fluid collections or abscess formation [10]. According to this scale, "mild" increase of 18F-FDG uptake means less than twice the blood pool activity in the ascending aorta, whereas "strong" means more than twice the blood pool activity in the ascending aorta. Similarly as described by Sah et al., in this work, in score 1 and 2 images were considered as negative, whereas in score 3, 4 and 5 as positive for graft infection.

Metabolic activity assessed by 18F-FDG uptake in of the vascular graft was also evaluated by semi-quantitative analysis by use of maximum standardized uptake values (SUV max). The SUV max was calculated as the ratio of decay-corrected activity per cubic centimeter of tissue to the injected dosage divided by body weight.

For the semi-quantitative evaluation of the SUV max value, the region of interest (ROI) was placed in the focal area of the most intense 18F-FDG uptake. The background region, for background SUV max evaluation, was placed in the ascending aorta in case of abdominal prosthesis, and in abdominal aorta in case of thoracic one.

There was also visual assessment of non-contrast enhanced CT performed during the 18F-FDG PET/CT examination. The CT findings in the vascular graft location were: gas bubbles, peri-graft fluid retention, thickening of the graft wall, adjacent blurred fat, soft tissue swelling, fistula and pseudoaneurysms.

In the final diagnosis of PVGI the MAGIC criteria of clinical, radiological and laboratory tests were taken into account.

Statistical analysis

All calculations were expressed as mean ± standard deviation (SD), as well as minimal and maximal values. Differences between study groups were assessed with the U-Mann-Whitney test; p value < 0.05 was considered to indicate statistical significance. Data were evaluated using the statistical package Statistica, version 7.

Ethics

The study was approved by the Bioethical Council, Medical University of Lublin, Poland. Informed consent was obtained from all participants. No side effects were observed after the radionuclide procedure.

Results

The analysis of vascular prostheses according to the both applied visual scales [9, 10] provided very similar results. In the 3-point scale: 23 patients were in grade 1 and one patient was in grade 2. In the 5-point scale: 19 patients were in grade 5 with the highest activity in the focal area, 4 patients were in grade 4 and one patient in grade 3. The first two points in 3-point scale and 3 last points in 5-point scale were recognized as PVGI.

The visual assessment revealed that peri-graft high metabolic, focal activity was associated with occurrence of gas bubbles, peri-graft fluid retention, thickening of the graft wall, adjacent blurred fat, soft tissue swelling, fistula and pseudoaneurysm (Fig. 1). In 3 cases (12.5%) increased focal 18F-FDG uptake in the infected grafts was found without morphological abnormalities (Fig. 2). The peri-graft fluid retention was observed in 16 patients, peri-graft gas in 15 patients, thickening around the graft wall, adjacent blurred fat and soft tissue swelling in 16 patients, fistula in 13 patients, pseudoaneurysm in 15 patients and metabolically active lymph nodes in the area of PVGI in 10 patients. The triad of CT sign as pseudoaneurysms, soft tissue swelling and peri-graft fluid deposition were seen in 15 patients.

The synthetic vascular graft prostheses were made of either polyester or PTFE, which are both used in endovascular and in open mode surgery. The highest metabolic activity, which was seen in the area of infection, was expressed by SUV max. In infected stent-grafts the metabolic activity came to SUV max 21.5, whereas in infected classical prosthesis was lower and came to SUV max 13. Only in one patient stent-graft was inserted in the thoracic aorta, and in 6 patients in the abdominal aorta. So because of the overall highest metabolic activity in the stent-graft generally, higher SUV max were observed in the abdominal prosthesis than in the thoracic one (21.5 vs.12.5). The metabolic activities expressed by SUVs in the infection area are presented in Table 2.

There were statistically significant differences ($p < 0.01$) between mean SUV max in the infected area of stent-grafts compared to classical prostheses (SUV max 14.4 ± 5.1 vs 8.39 ± 2.56; 7 vs 17 pts). This difference was less distinctive after background correction ($p<0.02$; SUV max 7.38 ± 4.07 vs 3.94 ± 1.31) (Tab. 3). The adjacent blurred fat and soft tissue swelling were combined with higher glucose metabolism compared to prostheses without these signs on CT scans ($p < 0.005$, SUV max 11.79 ± 4.08 vs 6.84 ± 2.90, 16 vs 8 pts), with similar p value after background

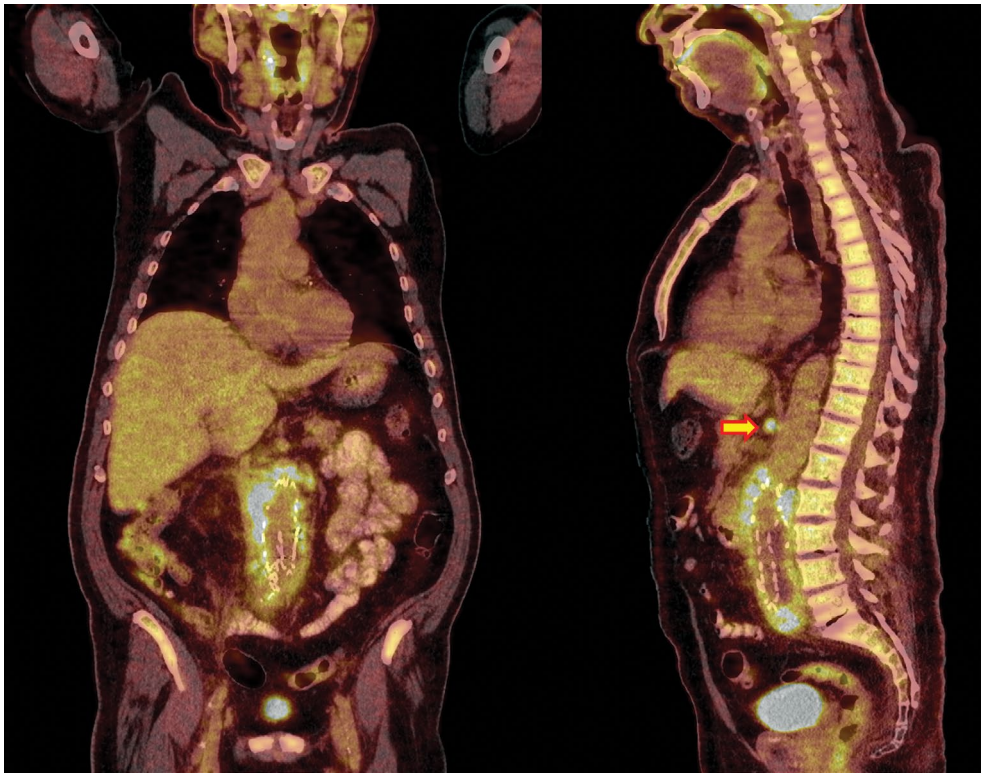

Figure 1. Increased 18F-FDG uptake associated with irregular peri-graft soft tissue swelling and fluid retention around infected aortic stentgraft, demonstrated on coronal and sagittal projections of 18F-FDG PET/CT. Infection in the paraaortic lymph node with high radiopharmaceutical activity (arrow)

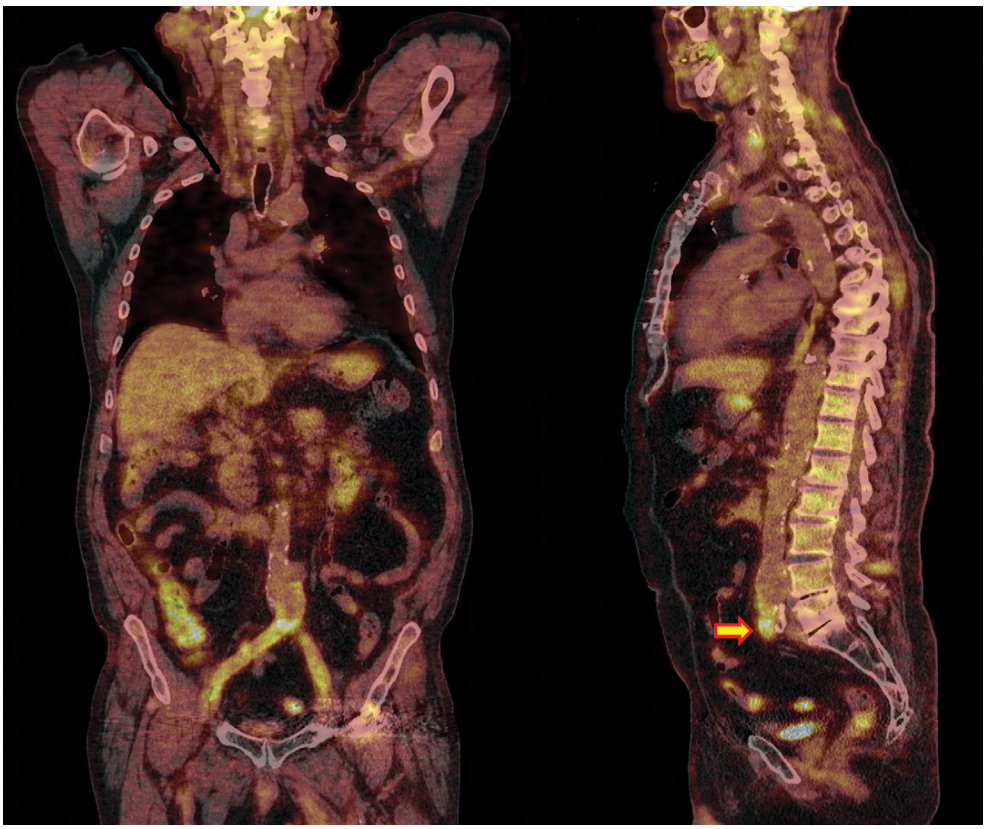

Figure 2. Focal 18F-FDG uptake (arrow) in infected classical prosthesis displayed on coronal and sagittal projections of 18F-FDG PET/CT

Table 2. SUV max in the area of suspected of infection

Prosthesis	n	SUV max in area suspected of infection		
		median	MAX	MIN
All	24	9.0	21.5	4.2
EVAR	7	8.3	13.0	4.2
Open mode	17	14.4	21.5	4.8
Abdominal	20	10.2	21.5	4.2
Thoracic	4	9.3	12.5	4.8

EVAR — endovascular aortic repair

correction (5.83 ± 3.12 vs 3.22 ± 1.39). The presence of the gas bubbles in adjacent tissue of prosthesis was linked to high uptake of 18F- FDG ($p < 0.01$, SUV max 11.81 ± 4.35 vs 7.36 ± 2.80, 15 vs 9 pts) as well as the peri-graft fluid retention, thickening of the peri-graft wall ($p < 0.05$, SUV max 5.61 ± 3.21 vs 3.62 ± 1.68, 16 vs. 8 pts). Findings are presented in Table 4. Table 5 contains correlation between visual grading scales and CT findings.

Microbiological findings were based on vascular graft, blood, wound, skin and fistula bacterial cultures. The culture were positive from prosthesis (*Proteus mirabilis, Staphylococcus aureus, Enterococcus faecalis*, *Clostridium difficile*), from fistula (*Proteus mirabilis, Staphylococcus aureus*, *Klebsiella pneumonia, Escherichia coli*), from blood (*Escherichia coli, Enterobacter cloacae*, *Streptococcus zooepidermicus*), in one patient *Candida albicans* were detected in urine. Some cultures were not conclusive (physiological skin culture or no bacterial growth). But in all patients, further clinical observation confirmed infections of PVG.

In the follow-up of the studied group, 3 patients died in the course of infection: one patient with stent-graft of the ascending aorta in course of an esophageal fistula and two patients with aorto-bi-iliac stent-grafts. There was one patient who lost a lower limb. In 4 patients surgical treatment of infected vascular graft was not performed because of general bad condition and instability of the patients. In those patients antibiotic therapy was continued. In the rest of our patients surgical replacement of prosthesis was performed.

Discussion

Removal of the infected prosthesis, and replacement with another device to revascularization by anatomical or uninfected extra-anatomical route is an essential vascular graft infection treatment, beyond antibiotic therapy [11]. There is 18–30% mortality rate after surgical explantation of infected aortic prosthesis whereas leaving the prosthesis at the site of infection, despite prolonged antimicrobial treatment, results in 100% mortality over the course of 2 years [10, 12, 13]. The distinction

Table 3. Statistically significant differences between SUVs in the stent-grafts compared to classical prostheses

SUVmax	Type of prosthesis	Mean (SD)	p
Without background correction	Stent-grafts	14.40 (SD = 5.01) n = 7 pts	
	classical prostheses	8.39 (SD = 2.64) n = 17 pts	$p < 0.01$
With background correction	Stent-grafts	7.38 (SD = 4.07) n = 7 pts	
	classical prostheses	3.94 (SD =1.30) n = 17 pts	$p < 0.02$

Table 4. Statistically significant differences between SUVs in the prosthesis with and without anatomic alterations on CT scans

SUVmax	CT finding	Mean (SD)	p
Without background correction	Gas bubbles	yes 11.81 (SD = 4.35) n = 15 pts	
		no 7.36 (SD = 2.80) n = 9 pts	$p < 0.01$
With background correction	Gas bubbles	yes 5.76 (SD = 3.23) n = 15 pts	$p < 0.01$
		no 3.58 (SD = 1.24) n = 9 pts	
With background correction	Peri-graft fluid retention	yes 5.61(SD = 3.21) n = 16 pts	
		no 3.62 (SD = 1,68) n = 8 pts	$p < 0.05$
Without background correction	Soft tissue swelling	yes 11.79 (SD = 4.08) n = 16 pts	$p < 0.005$
		no 6.84 (SD = 2.90) n = 8 pts	
With background correction	Soft tissue swelling	yes 5.80 (SD = 3.02) n = 16 pts	
		no 3.23(SD = 1.39) n = 8 pts	$p < 0.005$

Table 5. Correlation between CT findings and visual grading scales

* 3-point scale	** 5-point scale	n	Gas bubbles	Thrombus	Fluid	Infiltration	Fistula	Pseudo- aneurysm	Active lymph nodes
2	3	1	0	0	0	0	0	1	0
1	4	4	0	2	1	1	2	4	2
	5	19	15	9	15	15	11	10	8

*Three-point scale 1) focal (one dominant area of uptake), 2) inhomogeneous or patched uptake, and 3) diffuse or homogenous uptake; **Five-point scale 1), normal background activity; 2), mildly increased, but diffuse FDG uptake along the graft (mild uptake: less than twice the blood pool activity in the ascending aorta; strong uptake: more than twice the blood pool activity in the ascending aorta); 3), focal, but only mild FDG uptake or strong diffuse FDG uptake along the graft; 4), focal and intense FDG uptake (± diffuse FDG uptake along the graft); 5), focal and intense FDG uptake plus fluid collections/abscess formation

between infection and inflammation in reference to vascular prosthesis is very challenging, but absolutely crucial for the proper treatment. There are many various diagnostic schemes which include clinical, biochemical, microbiological and imaging procedures [12]. As in the MAGIC recommendation, the clinical criteria of PVGI were the start point of diagnosis [8]. There were major criteria like fistula development and infected pseudoaneurysm as well as minor criteria like erythema, warmth, swelling purulent discharge and pain. They occurred in all patients in various degrees. The serum levels of CRP and WBC belonging to the minor criteria in laboratory categories in MAGIC were increased in the studied patients. The golden standard in the diagnosis of PVGI is confirmation of bacterial colonization of prosthesis. In MAGIC criteria organisms recovered from explanted graft or recovered from intra-operative or radiologically guided aspiration of peri-graft belong to the major criteria of infections. Positive blood culture with no apparent source of infection except of AGI, are the minor criteria of infections [8]. *Staphylococcus* species are the most common causative organisms, *Staphylococcus aureus* are more likely in early infection and *Staphylococcus epidermidis* in late infections [13]. However, many suspected PVGI are treated without knowing the causative organisms, because as described by FitzGerald et al. suitable specimens could not be obtained or antibiotic treatment was applied before collection of samples [13]. Some authors stress that even if the specimens are taken from blood or from the suspicious location, there could be negative bacterial culture in active vascular prosthesis infections [14]. On the other hand, same pathogens isolated from superficial specimens may be misleading, but influence the choice of antimicrobial agents [13]. For this reason, antimicrobial treatment is empirical and based on clinical manifestations and findings, as well as on radiological/nuclear medical imaging.

Contrast-enhanced computed tomography has close to 100% sensitivity and specificity in diagnosis of acute PVGI, whereas in chronic PVGI up to 55% [15]. Presentation of periprosthesis air bubbles, abscesses or infiltration suggests vascular graft infections in CT. Nevertheless, it should be kept in mind that one week after vascular prosthesis implantation, air bubbles are present around the vascular prosthesis in 65% of patients [16]. Moreover, in 100% of patients periprosthetic hematoma is present in CT one week after surgery and in 10% of patients at 100 days post-surgery [17]. However, in all patients presenting air bubbles, periprosthetic infiltration or fluid collections 3 months post-surgery, the possibility of a vascular graft infection should be taken into account [13].

In nuclear medicine procedures there are two main techniques, SPECT and PET, and several radiopharmaceuticals like Gallium 67-citrate, radiolabeled white blood cells, antigranulocyte antibody. In the PET technique there is the main radiotracer 18F-FDG. According to the EANM/SNMMI guidelines [18], the advantage of use of 18F-FDG PET/CT over radiolabeled WBC scintigraphy in detection of infection in vascular prosthesis is unclear. However, the usage of 18F-FDG PET/CT is less time-consuming and much easier to perform compared to radiolabeled WBC scintigraphy. The reported sensitivity, specificity and accuracy of scintigraphy with radiolabeled WBC in PVGI is 100%, 92%, 97% respectively [19], whereas the latest study of 18F-FDG PET/CT presents sensitivity, specificity, positive and negative predictive value 88%, 79%, 67%, and 93% respectively [9].

18F-FDG PET/CT provides information regarding not only of the *anatomy* but also the *metabolism* of lesions. Three cases (12.5%) in the studied population presented increased 18F-FDG uptake in the infected grafts without morphological abnormalities on CT scans. In some patients 18F-FDG PET/CT also revealed extra-prosthetic infection in the lymph nodes. Therefore, an additional value of PET/CT over CT alone was documented in this study. Recently the combination of PET/CT with contrast enhanced CT is postulated in diagnosing PVGI as it was proved to be more accurate than stand-alone imaging and may be supportive in future management of difficult cases [20].

In the studied patients there were two types of vascular graft prosthesis: stent-grafts (EVAR procedure) and classic prostheses. All prostheses were made of either polyester or [7], which are both use in endovascular and open surgery. Synthetic vascular grafts provoke a chronic low-grade inflammation, therefore could be a cause of a false positive diagnosis [21]. Our material revealed higher metabolic activity in stent-grafts than classical prosthesis, but further studies are needed because of potentially higher artifacts from metallic elements contained in the stent-grafts. On the other hand, the number of patients in both groups was not very high.

Testing a short time after implantation could be a source of a false positive finding [22]. The mean time between the surgery and 18F-FDG PET/CT in the studied group of patients was 51 months, but in one patient imaging was performed 1 month after Bentall de Bono procedure, because of rapid progress of infection symptoms. This patient died over the course of the infection. However, generally in cases of very early assessment of vascular prosthesis, the diagnosis should be made very carefully. In the early period after implantation there are post-surgical inflammatory changes in the area of implantation, with physiological activation of leukocytes. Peri-graft fluid and peri-graft gas observed in CT integrated with PET meet the major criteria of aortic graft infection enclosed in MAGIC criteria [8]. They depend on the time after surgery, so persistent peri-graft fluid after more than 3 months and peri-graft gas after more than 7 weeks after insertion, suggest PVGI. In our analysis, except one patient, the time criteria have been met. In this study peri-graft fluid was observed in 16 and peri-graft gas in 15 patients. Presence of pseudoaneurysm and fistula are the minor criteria of MAGIC and in our study were observed in 15 and in 13 patients respectively.

Pattern of 18F-FDG uptake in patients with suspicion of vascular graft infection is very important. Focal or heterogeneous accumulation is highly suggestive of infection whereas moderate, homogeneous, linear uptake in the graft and/or surrounding tissue is often recognized as non-infectious [22, 23]. However, some authors underline that patterns of FDG uptake for uninfected grafts largely overlap with those of infected vascular graft [24]. In these cases it is very important to recognize all the additional signs of potential infection. Concerning the 18F-FDG uptake and distribution patterns, reported sensitivity, specificity, positive predictive value and negative predictive value in PVGI are 93%, 91%, 88%, 96% respectively [25]. In this study of analysis of 18F-FDG uptake in prosthesis and in the surrounding tissues two visual scales were applied [9, 10]. Both of them presented very similar results, FDG uptake was focal (mild to intense) in all patients. 18F-FDG PET/CT as hybrid study additionally revealed in our patients signs of infections in CT, like: gas bubbles, peri-graft fluid retention, thickening of

the graft wall, adjacent blurred fat, soft tissue swelling, fistula and pseudoaneurysm. All the patients in the study were positive in reference to infection. Moreover, in MAGIC criteria increased peri-graft 18F-FDG activity fulfills the minor criteria of aortic graft infection [8].

On the other hand, based only on assessment of 18F-FDG uptake it is very difficult to differentiate a quite rare condition like retroperitoneal fibrosis (RPF), which could be also secondary to vascular graft implantation from a simple inflammatory reaction to a foreign body or the early phase of an infection. In all these conditions there is increased 18F-FDG uptake and serum level of inflammatory markers, as well as clinical symptoms like fever and pain. In RPF treatment is based on glucocorticosteroids application, in inflammation as foreign body reaction – watchful waiting is much advisable, whereas in the last case redo surgery is usually performed. Therefore, it should be kept in mind, that diagnosis of PVGI should be based on multidisciplinary consensus [26].

Conclusions

18F-FDG PET/CT is a very useful, non-invasive tool for assessment of vascular graft infections. It should be interpreted with caution in multidisciplinary teem. CT findings like gas bubbles, peri-graft fluid retention, thickening of the graft wall and adjacent blurred fat soft tissue swelling are associated with significantly higher glucose metabolism: however, in some cases without anatomic alterations, increased metabolic activity is the only sign of infection. A useful marker of infected graft is focal not homogeneous pattern of 18F-FDG uptake found in all examined cases.

Conflict of interest

The authors declare that they do not have any conflict of interest.

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