

World Journal of *Radiology*

World J Radiol 2023 August 28; 15(8): 241-255



ORIGINAL ARTICLE**Retrospective Study**

- 241 Appearance of aseptic vascular grafts after endovascular aortic repair on [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography

Bennett P, Tomas MB, Koch CF, Nichols KJ, Palestro CJ

CASE REPORT

- 250 Rare portal hypertension caused by Abernethy malformation (Type IIC): A case report

Yao X, Liu Y, Yu LD, Qin JP

ABOUT COVER

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Retrospective Study

Appearance of aseptic vascular grafts after endovascular aortic repair on [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography

Paige Bennett, Maria Bernadette Tomas, Christopher F Koch, Kenneth J Nichols, Christopher J Palestro

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Abstract

BACKGROUND

Diagnosis of prosthetic vascular graft infection with [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography (18F-FDG PET/CT) allows for early detection of functional changes associated with infection, based on increased glucose utilization by activated macrophages and granulocytes. Aseptic vascular grafts, like all foreign bodies, can stimulate an inflammatory response, which can present as increased activity on 18F-FDG PET/CT. Consequently, distinguishing aseptic inflammation from graft infection, though important, can be difficult. In the case of endovascular aneurysm repair (EVAR), a minimally invasive procedure involving the transfemoral insertion of an endoprosthetic stent graft, the normal postoperative appearance of these grafts on 18F-FDG PET/CT can vary over time, potentially confounding study interpretation.

AIM

To investigate the visual, semiquantitative, and temporal characteristics of aseptic vascular grafts in patients status post EVAR.

METHODS

In this observational retrospective cohort study, patients with history of EVAR who underwent 18F-FDG PET/CT for indications other than infection were

identified retrospectively. All patients were asymptomatic for graft infection - no abdominal pain, fever of unknown origin, sepsis, or leukocytosis - at the time of imaging and for ≥ 2 mo after each PET/CT. Imaging studies such as CT for each patient were also reviewed, and any patients with suspected or confirmed vascular graft infection were excluded. One hundred two scans performed on 43 patients (34 males; 9 females; age = 77 ± 8 years at the time of the final PET/CT) were retrospectively reviewed. All 43 patients had an abdominal aortic (AA) vascular graft, 40 patients had a right iliac (RI) limb graft, and 41 patients had a left iliac (LI) limb graft. Twenty-two patients had 1 PET/CT and 21 patients had from 2 to 9 PET/CTs. Grafts were imaged between 2 mo to 168 mo (about 14 years) post placement. Eight grafts were imaged within 6 mo of placement, including three that were imaged within three months of placement. The mean interval between graft placement and PET/CT for all 102 scans was 51 ± 39 mo. PET/CT data was reconstructed with region-of-interest analysis of proximal, mid and distal portions of the grafts and background ascending aorta. Maximum standardized uptake value (SUV_{max}) was recorded for each region. SUV_{max} -to-background uptake ratios (URs) were calculated. Visual assessment was performed using a 2-pattern grading scale: Diffuse (homogeneous uptake less than liver uptake) and focal (one or more areas of focal uptake in any part of the graft). Statistical analysis was performed.

RESULTS

In total, there were 306 AA grafts, 285 LI grafts, 282 RI grafts, and 306 ascending aorta background SUV_{max} measurements. For all 102 scans, mean SUV_{max} values for AA grafts were 2.8-3.0 along proximal, mid, and distal segments. Mean SUV_{max} values for LI grafts and RI grafts were 2.7-2.8. Mean SUV_{max} values for background were 2.5 ± 0.5 . Mean URs were 1.1-1.2. Visual analysis of the scans reflected results of quantitative analysis. On visual inspection, 98% revealed diffuse, homogeneous 18F-FDG uptake less than liver. Graft URs and visual pattern categories were significantly associated for AA graft URs (F-ratio = 21.5, $P < 0.001$), LI graft URs (F-ratio = 20.4, $P < 0.001$), and RI graft URs (F-ratio = 30.4, $P < 0.001$). Thus, visual patterns of 18F-FDG uptake corresponded statistically significantly to semiquantitative URs. The age of grafts showing focal patterns was greater than grafts showing diffuse patterns, 87 ± 89 vs 50 ± 37 mo, respectively ($P = 0.02$). URs were significantly associated with graft age for AA grafts ($r = 0.19$, $P = 0.001$). URs were also significantly associated with graft age for LI grafts ($r = 0.25$, $P < 0.0001$), and RI grafts ($r = 0.31$, $P < 0.001$). Quartiles of similar numbers of graft ($n = 25-27$) grouped by graft age indicated that URs were significantly higher for 4th quartile vs 2nd quartile URs (F-ratio = 19.5, $P < 0.001$). When evaluating URs, graft SUV_{max} values within 10%-20% of the ascending aorta SUV_{max} is evident in aseptic grafts, except for grafts in the oldest quartiles. In this study, grafts in the oldest quartiles (> 7 years post EVAR) showed SUV_{max} up to 30% higher than the ascending aorta SUV_{max} .

CONCLUSION

Characteristics of an aseptic vascular stent graft in the aorta and iliac vessels on 18F-FDG PET/CT include graft SUV_{max} values within 10%-20% of the ascending aorta background SUV_{max} . The SUV_{max} of older aseptic grafts can be as much as 30% above background. The visual uptake pattern of diffuse, homogeneous uptake less than liver was seen in 98% of aseptic vascular grafts, making this pattern particularly reassuring for clinicians.

Key Words: Aseptic vascular grafts; Endovascular aortic repair; [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography

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Core Tip: In patients post endovascular aortic repair who undergo [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography, aseptic vascular grafts show maximum standardized uptake value (SUV_{max}) within 10%-20% of background ascending aorta SUV_{max} values. Older aseptic vascular grafts can show up to 30% higher uptake vs background compared with younger aseptic vascular grafts. The visual uptake pattern of diffuse, homogeneous uptake less than liver was seen in 98% of aseptic vascular grafts, making this pattern particularly reassuring for clinicians.

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INTRODUCTION

Diagnosis of prosthetic vascular graft infection with [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography (18F-FDG PET/CT) allows for detection of early functional changes associated with infection, based on

increased glucose utilization by activated macrophages and granulocytes. 18F-FDG PET/CT can be an important diagnostic adjunct to CT, which depends on anatomic changes, such as perigraft air, fluid, soft tissue, fistula, and abscess for diagnosis of infection. However, sterile vascular grafts, like all foreign bodies, can stimulate an aseptic inflammatory response that presents as increased activity on 18F-FDG PET/CT. Consequently, distinguishing aseptic inflammation from vascular graft infection can be difficult, and standardized interpretation criteria for differentiating between these two conditions have not been universally adopted[1].

Currently, medical literature supports diagnostic sensitivity and specificity of 18F-FDG PET/CT in diagnosing vascular graft infection of 89%-98% and 59%-81%, respectively[2,3]. Note that the lower specificity raises the possibility of false-positive interpretations of 18F-FDG uptake on PET/CT. This has important clinical consequences, including unnecessary long-term antibiotic therapy, invasive procedures, and potential for graft explantation which carries an 18%-30% mortality rate due to complications[1,4,5]. As the negative predictive value of 18F-FDG PET/CT for excluding vascular graft infection is high (about 93%), the expected physiological patterns of 18F-FDG uptake in uninfected vascular grafts should be identified to avoid false-positive interpretation[4,6].

However, evidence on the appearance of aseptic vascular grafts over time on 18F-FDG PET/CT is sparse, maximum standardized uptake value (SUV_{max}) cutoff values for aseptic grafts have not been clearly defined, and visual pattern analysis is often suggested to distinguish aseptic from infected vascular grafts[2,7-10]. In the case of endovascular aneurysm repair (EVAR), a minimally invasive procedure involving the transfemoral insertion of an endoprosthetic stent graft, the normal postoperative appearance of these grafts on 18F-FDG PET/CT can vary over time, potentially confounding study interpretation[11,12]. Thus, this study was performed to evaluate visual, semiquantitative, and temporal characteristics of aseptic endovascular aneurysm grafts on 18F-FDG PET/CT.

MATERIALS AND METHODS

Patients

In this observational retrospective cohort study, patients with history of EVAR who underwent 18F-FDG PET/CT for indications other than infection were identified retrospectively. All patients were asymptomatic for graft infection - no abdominal pain, fever of unknown origin, sepsis, or leukocytosis - at the time of imaging and for ≥ 2 mo after each PET/CT. Imaging studies such as CT for each patient were also reviewed, and any patients with suspected or confirmed vascular graft infection were excluded. One hundred two scans performed on 43 patients (34 males; 9 females; age = 77 ± 8 years at the time of the final PET/CT) were retrospectively reviewed. All 43 patients had an abdominal aortic (AA) vascular graft, 40 patients had a right iliac (RI) limb graft, and 41 patients had a left iliac (LI) limb graft. Twenty-two patients had 1 PET/CT and 21 patients had from 2 to 9 PET/CTs. Grafts were imaged between 2 mo to 168 mo (about 14 years) post placement. Eight grafts were imaged within 6 mo of placement, including three that were imaged within three months of placement. The mean interval between graft placement and PET/CT for all 102 scans was 51 ± 39 mo. Types of graft material were obtained from the patients' medical records, when available ($n = 19$). The Institutional Review Board approved this retrospective study and the requirement to obtain informed consent was waived. All data were handled in compliance with the Health Insurance Portability and Accountability Act of 1996.

Data acquisition

Data were acquired on 4 PET/CT systems: 2 Siemens Biograph mCT 64 (Munich, Germany) and 2 GE D710 (GE Healthcare, Chicago, IL, United States) systems. Data were reconstructed using manufacturer recommended 18F-FDG PET/CT reconstruction parameters on associated workstations at which data were acquired.

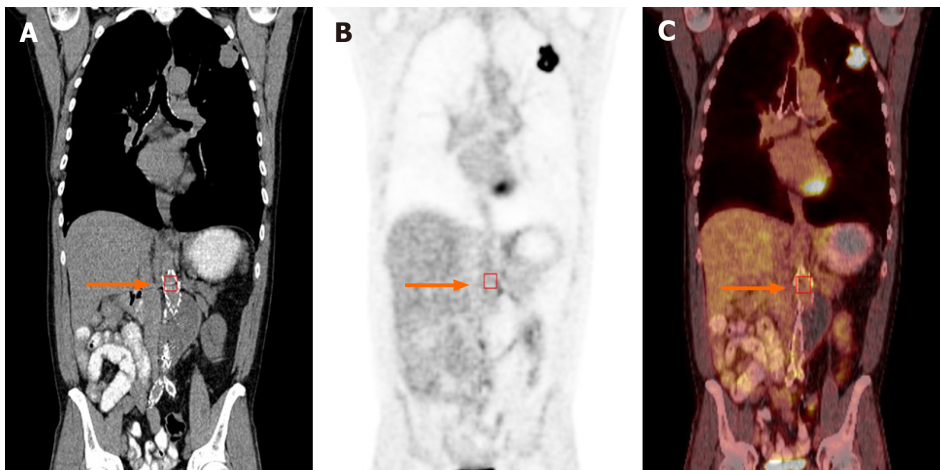
Image analysis

All reconstructed data were reviewed on a single GE AW workstation (GE Healthcare, Chicago, IL, United States). One nuclear medicine physician (MBT) analyzed all PET/CT images and obtained semiquantitative SUV_{max} using manually drawn region of interest (ROI) analysis. For each graft, a square ROI was drawn encompassing the width of the graft, cross-referenced on CT and confirmed on fused PET/CT images (Figure 1). ROIs were drawn around the proximal, mid, and distal portions of the AA graft, and SUV_{max} was recorded for each region. A similar ROI was used to measure SUV_{max} in the ascending aorta as the background (BKG) reference. SUV_{max} was also measured at proximal, mid, and distal portions of the RI and LI grafts when present. ROIs for each of the 3 locations along the grafts were placed equidistant.

Analyses were performed for SUV_{max} values to avoid underrepresentation of 18F-FDG uptake that could result from sampling tissue outside of graft tissues. To avoid the possibility of different PET/CT systems or software generating SUV_{max} values that were different from one another, the uptake ratio (UR) of SUV_{max} was calculated for each graft location using the formula: $UR = SUV_{max} \text{ graft} / SUV_{max} \text{ BKG}$. The URs were analyzed to minimize effects of using different PET/CT systems and image reconstruction algorithms.

Visual assessment

The same nuclear medicine physician who placed ROIs for semiquantitative analysis also classified uptake according to two visual patterns for aseptic grafts: Diffuse and focal. Diffuse was defined as mild, homogeneous uptake less than liver. Focal was defined as one or more areas of focal uptake in any part of the graft. Reference for visual analysis was 18F-FDG uptake in the liver.



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Figure 1 Coronal [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography showing example of region of interest analysis on an abdominal aortic graft (arrow). A: Non-contrast computed tomography (CT); B: Positron emission tomography (PET); C: Fused PET/CT images.

Statistical analysis

Analyses were performed using commercially available software ("MedCalc" Statistical Software version 20.110; MedCalc Software Ltd, Ostend, Belgium; <https://www.medcalc.org>; 2022). Values were reported as mean $\pm$ SD. The Kolmogorov-Smirnov method assessed whether continuous variables were normally distributed and provided means and distribution percentiles. ANOVA with Bonferroni correction compared SUV_{max} and URs grouped by age of grafts, ROI locations, and graft material. Significance of differences between mean values were assessed by the unpaired student's *t*-test for normally distributed variables and by the Mann-Whitney test for non-normally distributed variables. Significance of changes over time was determined by linear regression of URs *vs* graft age. Linear regression of URs *vs* the time difference from the first through the last scan was performed for each patient with more than 1 PET/CT. Also, a separate subgroup analysis of patients with 3 or more scans was performed similarly with URs compared with the time difference from the first through the last scan of each patient. The Tukey test was applied to URs to detect outliers. For all tests, $P < 0.05$ was defined as statistically significant, or as adjusted by Bonferroni corrections for comparisons among multiple categories.

RESULTS

In total, there were 306 AA grafts, 285 LI grafts, 282 RI grafts, and 306 BKG SUV_{max} measurements. For all 102 scans, mean SUV_{max} values for AA grafts were 2.8-3.0 along proximal, mid, and distal segments (Table 1). Mean SUV_{max} values for LI grafts and RI grafts were 2.7-2.8. Mean SUV_{max} values for BKG were 2.5 ± 0.5 (Table 2). Mean URs were 1.1-1.2 (Tables 1 and 2).

Of the 43 patients, graft material was identifiable for 10 patients who had polyethylene terephthalate (PT) grafts and 9 patients who had polytetrafluoroethylene (PTFE) grafts. There were 87 SUV_{max} measurements of PT grafts and 78 SUV_{max} measurements of PTFE grafts. ANOVA indicated a modest difference (F-ratio = 5.1, $P = 0.03$) of AA graft URs between PT and PTFE graft materials (1.2 ± 0.3 *vs* 1.1 ± 0.2 , $P = 0.03$).

URs were significantly associated with graft age for AA grafts ($r = 0.19$, $P = 0.001$) (Figure 2). URs were also significantly associated with graft age for LI grafts ($r = 0.25$, $P < 0.0001$), and RI grafts ($r = 0.31$, $P < 0.001$). Quartiles of similar numbers of graft ($n = 25-27$) grouped by graft age indicated that URs were significantly higher for 4th quartile *vs* 2nd quartile URs (F-ratio = 19.5, $P < 0.001$) (Table 3). URs were similar for patients for whom graft placement was < 3 mo *vs* those with older grafts and were likewise similar for patients for whom graft placement was < 6 mo *vs* those with older grafts (F-ratio < 2.0 , $P > 0.05$). While correlation of URs versus graft age was significant for all AA grafts (Figure 2), when analyzed separately by location, strongest correlation *vs* AA graft age was for proximal ROIs, less strong for mid ROIs, and not significant for distal ROIs (Figure 3). The highest UR value (2.89) corresponded to the patch region of the graft in one patient.

Patients with multiple PET/CT studies

A total of 80 18F-FDG PET/CTs were performed on the 21 patients with repeat scans: 5 patients had 2; 8 patients had 3; 3 patients had 4; 3 patients had 6; 1 patient had 7; and 1 patient had 9 scans. Correlations of URs over time from the first through the last scan were not significant ($r = 0.10$, $P = 0.09$) (Figure 4). There were 210 URs evaluated for the subgroup of patients with 3 or more scans. For this subgroup, URs were not correlated with time from the first through the last scan ($r = 0.12$, $P = 0.07$).

Table 1 Maximum standardized uptake value and uptake ratios for aortic graft locations

Location	SUV _{max}	Uptake ratio
Proximal aortic graft	2.8 ± 0.8	1.1 ± 0.3
Mid aortic graft	2.9 ± 0.8	1.2 ± 0.3
Distal aortic graft	3.0 ± 0.9	1.2 ± 0.3
Background	2.5 ± 0.5	-

SUV_{max}: Maximum standardized uptake value.

Table 2 Maximum standardized uptake value for grafts and background (ascending aorta), uptake ratios are listed for grafts

Location	SUV _{max}	Uptake ratio
Aortic graft	2.9 ± 0.8	1.2 ± 0.3
Left Iliac graft	2.7 ± 0.8	1.1 ± 0.3
Right Iliac graft	2.8 ± 0.8	1.2 ± 0.4
Background	2.5 ± 0.5	-

SUV_{max}: Maximum standardized uptake value.

Table 3 Graft age and uptake ratios segregated into quartiles by graft age

Graft, age, quartile	Graft age (mo)	Uptake ratio		
		Aortic graft	L-iliac graft	R-iliac graft
1	9 ± 4	1.2 ± 0.2	1.1 ± 0.2 ^a	1.1 ± 0.2 ^a
2	31 ± 10	1.1 ± 0.2 ^a	1.1 ± 0.2 ^a	1.1 ± 0.2 ^a
3	60 ± 9	1.1 ± 0.3 ^a	1.1 ± 0.3 ^a	1.1 ± 0.4 ^a
4	107 ± 24	1.3 ± 0.3	1.3 ± 0.4	1.4 ± 0.4

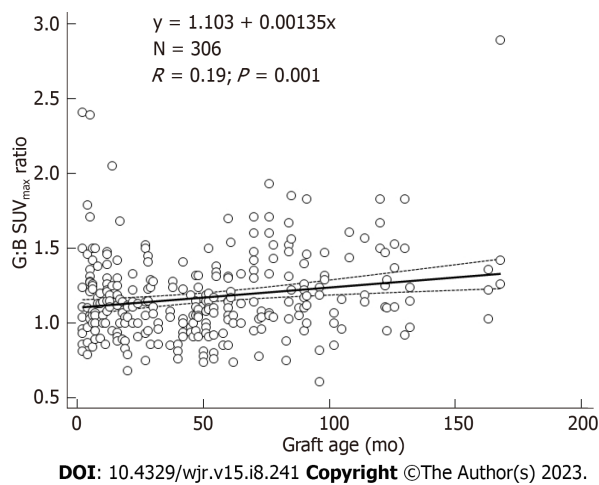
^a*P* < 0.05 versus graft age quartile #4.

Figure 2 Graft uptake ratios vs graft age in months for abdominal aortic grafts. SUV_{max}: Maximum standardized uptake value.

Visual analyses

Visual analysis of the scans reflected results of quantitative analysis (Table 4). On visual inspection, 98% revealed diffuse, homogeneous 18F-FDG uptake less than liver. Graft URs and visual pattern categories were significantly associated for AA graft URs (F-ratio = 21.5, $P < 0.001$), LI graft URs (F-ratio = 20.4, $P < 0.001$), and RI graft URs (F-ratio = 30.4, $P < 0.001$). Thus, visual patterns of 18F-FDG uptake corresponded statistically significantly to semiquantitative URs. The age of grafts showing focal patterns was greater than grafts showing diffuse patterns, 87 ± 89 vs 50 ± 37 mo, respectively ($P = 0.02$).

Visual uptake patterns were similar for different graft materials, when known, in that similar percentages of PT grafts and PTFE grafts were scored with focal visual patterns (2% vs 1%, $P = 0.63$) (Table 5), and similar to the 2% (6/306) of focal visual patterns for all grafts (Table 4).

Tests for outliers

The Tukey test showed there were 3 outlier cases for 3 different patients among the 306 graft URs. Even after excluding these 3 cases, there was significant association with URs and graft age for AA graft URs ($r = 0.19$, $P = 0.001$) (Figure 2). Similarly, there was significant association with URs and graft age for LI graft URs ($r = 0.25$, $P < 0.001$) and RI graft URs ($r = 0.31$, $P < 0.001$). Thus, no results were altered by excluding the 3 outliers.

DISCUSSION

In this study, the 18F-FDG PET/CT appearance of aseptic vascular grafts was delineated on 43 patients post EVAR without clinical signs and symptoms of vascular graft infection who underwent 18F-FDG PET/CT for oncologic indications. Visual, semiquantitative SUV_{max} and graft-to-background UR analysis was performed for 306 AA grafts, 285 LI grafts and 282 RI grafts. To our knowledge, this is the largest analysis of aseptic vascular graft appearance on 18F-FDG PET/CT to date.

All patients with aseptic aortic and iliac grafts showed graft SUV_{max} values of 3 or below. This is supported by a study by Tsuda *et al* [13] showing SUV_{max} below 4.5 in uninfected grafts, which was not dependent on time after surgery or whether the graft was placed in an open or endovascular fashion. Other studies have reported SUV_{max} values greater than 3.8-4.5 as significant for infection, which is supported by this study showing lower SUV_{max} values in aseptic grafts [14,15].

As SUV_{max} values can vary based on differences in PET/CT scanners, reconstruction algorithms and quality control efforts, we chose to include graft-to-background URs in our analyses. When evaluating URs, graft SUV_{max} values within 10%-20% of the ascending aorta SUV_{max} is evident in aseptic grafts, except for grafts in the oldest quartiles. In this study, grafts in the oldest quartile (> 7 years post EVAR) showed SUV_{max} up to 30% higher than the ascending aorta SUV_{max} .

The highest difference in URs was evident in PT grafts compared to PTFE grafts, although this modest difference is likely not clinically significant (1.2 ± 0.3 vs 1.1 ± 0.2 , $P = 0.03$). When vascular grafts are encountered in the PET/CT clinic, two measurements of the ascending aorta and the graft can help to confirm a clinically noninfected appearance.

Visual analysis of vascular grafts in these patients was useful to detect a diffuse, homogeneous pattern of 18F-FDG uptake less than liver uptake, with results comparable to semiquantitative SUV_{max} and UR analysis. This suggests that visual comparison to the liver during image evaluation can be used to confirm a noninfected graft. The uptake pattern of 18F-FDG in aseptic vascular grafts was usually diffuse (300/306 = 98%), making this pattern particularly reassuring for clinicians.

When considering graft age, our data show a tendency for older grafts to exhibit higher 18F-FDG uptake. Those in the oldest quartile of the study (mean age 107 ± 24 mo) had mean URs of 1.3-1.4. Grafts in the lower 3 graft-age quartiles had mean URs closer to 1.1. Therefore, clinicians should consider the possibility of graft SUV_{max} being as much as 30% above ascending aorta background for old vascular grafts, particularly in proximal graft regions.

Limitations of this study include its retrospective nature, with chart review analysis the only means available to confirm absence of vascular graft infection in these patients. In addition, not all patients had contrast-enhanced CT for correlation with presence or absence of findings of vascular graft infection on anatomic imaging. Information regarding graft material composition was not available on all patients, potentially limiting analysis based on graft material. Another limitation is that a sole reader evaluated all data points on the PET/CT scans, including SUV_{max} and visual analysis. Therefore, interobserver variability in interpretation was not analyzed. Finally, our study did not include analysis of 18F-FDG PET/CT in patients with suspected or confirmed vascular graft infections, to compare with findings in aseptic vascular grafts in a similar patient population.

CONCLUSION

For 18F-FDG PET/CT interpreters, the visual, semiquantitative, and temporal characteristics of aseptic vascular stent grafts in patients' status post EVAR can be useful in interpreting PET/CT, whether stent grafts are encountered as incidental findings on oncologic scans or on scans performed for suspected vascular graft infection. Our findings reinforce prior research in determining the characteristics of aseptic vascular grafts in a large cohort of grafts analyzed over time.

Table 4 Frequency of visual uptake patterns for all grafts and uptake ratios

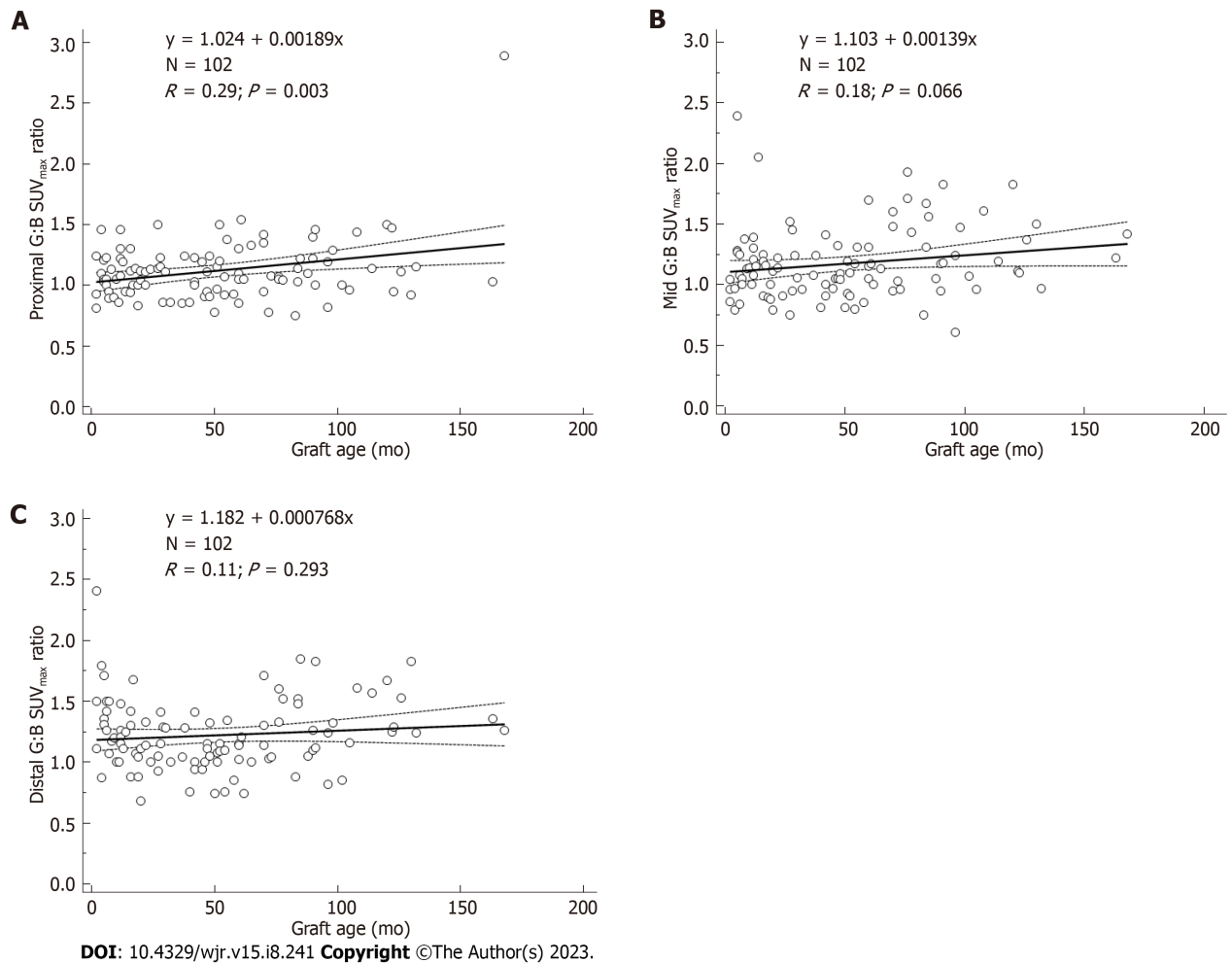
Visual uptake pattern	<i>n</i>	Uptake ratio
Diffuse	300	1.1 ± 0.3
Focal	6	1.8 ± 0.7 ^a

^a*P* < 0.05 versus “Diffuse”.**Table 5** Frequency of visual uptake patterns and uptake ratios analyzed by graft type

Visual uptake pattern	PT grafts		PTFE grafts	
	<i>n</i>	Uptake ratio	<i>n</i>	Uptake ratio
Diffuse	85	1.2 ± 0.3	77	1.1 ± 0.2
Focal	2	1.9 ± 0.7 ^a	1	1.5

^a*P* < 0.05 versus “Diffuse”.

PT: Polyethylene terephthalate; PTFE: Polytetrafluoroethylene.

**Figure 3** Uptake ratios vs graft age in months. A: Proximal regions; B: Mid regions; C: Distal regions of abdominal aortic grafts.

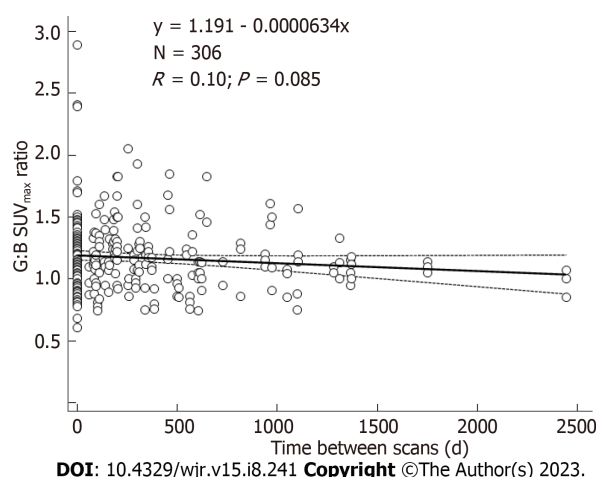


Figure 4 Uptake ratios of abdominal aortic grafts for all patients at all scan times. SUV_{max} : Maximum standardized uptake value.

ARTICLE HIGHLIGHTS

Research background

On [(18)F]fluorodeoxyglucose positron emission tomography/computed tomography (18F-FDG PET/CT), the inflammatory response caused by endoprosthetic stent grafts after endovascular aneurysm repair (EVAR) can show increased 18F-FDG uptake. However, the visual, semiquantitative, and temporal characteristics of uninfected, or aseptic, endovascular aneurysm grafts has not been fully elucidated.

Research motivation

Characterization of aseptic vascular stent grafts on 18F-FDG PET/CT is important to distinguish the normal inflammatory response to graft material *vs* vascular graft infection.

Research objectives

The purpose of this study was to characterize aseptic vascular stent grafts over time.

Research methods

In this observational retrospective cohort study, patients with EVAR who underwent 18F-FDG PET/CT for routine oncologic indications were included. Any patients with suspected or confirmed vascular stent graft infection were excluded. Visual and semiquantitative region of interest (ROI) analysis with maximum standardized uptake value (SUV_{max}) and graft-to-background ascending aorta uptake ratios (URs) of the grafts were obtained. We compared visual analysis and semiquantitative values, grouped by age of grafts, ROI locations, and graft materials.

Research results

Characteristics of an aseptic vascular stent graft on 18F-FDG PET/CT include graft SUV_{max} values within 10%-20% of the ascending aorta background SUV_{max} . The SUV_{max} of older aseptic grafts can be as much as 30% above background. The visual uptake pattern of diffuse, homogeneous uptake less than liver was seen in 98% of aseptic vascular stent grafts.

Research conclusions

Aseptic vascular stent grafts post endovascular repair show mildly increased 18F-FDG uptake, with mean graft-to-background URs of 1.1-1.2. Diffuse homogeneous 18F-FDG uptake less than liver in vascular stent grafts is particularly reassuring as a sign of an uninfected graft.

Research perspectives

This study reinforces prior research in characterizing aseptic vascular grafts on 18F-FDG PET/CT.

FOOTNOTES

Author contributions: Bennett P and Nichols KJ wrote the manuscript; Palestro C, Nichols KJ, and Tomas MB designed the research study; Tomas MB performed image analysis and chart review; Koch CF performed chart review; Nichols KJ, Tomas MB and Palestro C analyzed the data; and all authors have read and approved the final manuscript.

Institutional review board statement: Our Institutional Review Board approved this retrospective study. All data were handled in compliance with the Health Insurance Portability and Accountability Act of 1996.

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