Influence of Bowel Preparation Before $^{18}$F-FDG PET/CT on Physiologic $^{18}$F-FDG Activity in the Intestine

Jan D. Soyka$^1$, Klaus Strobel$^1$, Patrick Veit-Haibach$^1$, Niklaus G. Schaefer$^1$, Daniel T. Schmid$^1$, Alois Tschopp$^2$, and Thomas F. Hany$^1$

$^1$Department of Nuclear Medicine, University Hospital, Zurich, Switzerland; and $^2$Department for Biostatistics, University of Zurich, Zurich, Switzerland

Our objective was to investigate the use of bowel preparation before $^{18}$F-FDG PET/CT to reduce intestinal $^{18}$F-FDG uptake. Methods: Sixty-five patients with abdominal neoplasias were assigned either to a bowel-preparation group ($n = 26$) or to a native group ($n = 39$). $^{18}$F-FDG activity was measured in the small intestine and the colon. Results: In the 26 patients with bowel preparation, average maximal standardized uptake value (SUVmax) was $3.5$ in the small intestine and $4.4$ in the colon. In the 39 patients without bowel preparation, average SUVmax was $2.6$ in the small intestine and $2.7$ in the colon. $^{18}$F-FDG activity im-

mation group ($S$) was significantly higher in the bowel-prepara-

tion is only faint or moderate and diffuse. Such a pattern is

physiologic $^{18}$F-FDG uptake in the bowel can lead to
dsatisfaction to the patients ($I$). In general, such tracer accumu-
lution is often faint or moderate and diffuse. Such a pattern is

bowl preparation increases $^{18}$F-FDG activity in the large

In the daily clinical routine of reading $^{18}$F-FDG PET/CT scans, physiologic intestinal uptake of the tracer is frequently observed ($I$). In general, such tracer accumula-

tion is not significantly differ between the 2 groups ($P = 0.088$). Conclusion: Bowel preparation increases $^{18}$F-FDG activity in the large intestine and is therefore not useful before PET/CT.

Key Words: gastroenterology; oncology; PET/CT; FDG uptake; bowel preparation; intestinal; physiologic

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Preparations

Patients in the bowel-preparation group had to drink 75 mL of the senna-glycoside solution together with 2 L of tap water by 2 PM the day before the PET/CT examination. After ingestion of the solution, no more solid meals were allowed. Complete fasting was necessary for at least 4 h before the scheduled examination. Patients in the native group had to fast for at least 4 h before the examination as part of our routine procedure. No oral contrast agent was administered to either of the groups.

PET/CT

PET/CT was performed as a clinical procedure according to the routine parameters used at our institution (9).

Image Evaluation and SUVmax Measurements

Images were evaluated on commercially available Advantage workstations (version 4.4; GE Healthcare) by 2 physicians board-certified in both radiology and nuclear medicine, reading by consensus. The readers were unaware of the group assignment.

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For correspondence or reprints contact: Jan D. Soyka, Department of Nuclear Medicine, University Hospital Zuerich, Raemistrasse 100, 8091 Zuerich, Switzerland.
E-mail: jan.soyka@usz.ch
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and history of the patients. The purge was qualitatively assessed by determining whether intraluminal stool was visible in the 4 portions of the colon (ascending, transverse, descending, and sigmoid/rectum). An additional quantitative assessment was performed by measuring the maximal diameters of the 4 portions of the colon. Maximal standardized uptake values (SUVmax) were obtained from the small intestine as a whole and from the different parts of the colon by creating a volume of interest over the region with the visually highest tracer activity. No differentiation was made between bowel wall and lumen. Additionally, a 4-step scoring system for the areas with the highest 18F-FDG activity in the small intestine and colon was applied. The scoring system used the liver and brain as reference sites (Table 1). Finally, the influence of intestinal 18F-FDG accumulation on diagnostic image quality was evaluated. Any focal 18F-FDG accumulation within the colon was regarded as a factor leading to diagnostic uncertainty. Thus, diagnostic impairment was postulated for those patients. Diffuse 18F-FDG accumulations were not considered suggestive of malignancy. Therefore, no diagnostic impairment was postulated.

Statistical Analysis
Statistical analysis was performed using the Mann–Whitney and Pearson χ² tests. A P value of less than 0.05 was considered to indicate statistical significance.

RESULTS
Patient and Disease Characteristics
All patients had primary abdominal malignancies. Fifty-one patients had a history of colorectal carcinoma (78%), 11 had gynecologic malignant disease (17%), 2 had gastric carcinoma (3%), and 1 had pancreatic cancer (2%). Twelve patients were scanned for primary staging, and 53 were examined for follow-up or because of suspected recurrence. Most patients had advanced disease, stage III or IV (n = 45). Seven patients had received no treatment before PET/CT; the others had undergone surgery (n = 16) or had received chemotherapy (n = 2) or multimodal therapy (n = 40). The average interval between the last therapy and PET/CT was 11 mo in the bowel-preparation group and 13 mo in the native group. Statistical analysis showed no significant difference between the 2 groups regarding sex (P = 1), age (P = 0.874), tumor entity (P = 0.598), tumor stage (P = 0.871), reason for examination (primary staging, follow-up, or recurrence) (P = 0.836), previous treatment (P = 0.262), or interval between last treatment and PET/CT (P = 0.872).

Native Versus Bowel-Preparation Groups
Twenty-six patients were included in the bowel-preparation group and 39 in the native group. In the bowel-preparation group, 2 patients had undergone previous resection of the sigmoid/rectum. In the native group, 4 patients had undergone previous resection of the ascending colon, 1 of the transverse colon, and 1 of the descending colon. The assessment of purge efficiency showed that significantly more patients in the native group had visible stool in all colonic segments (Table 2). Except for the descending colon, the average diameters of each colonic segment were also significantly larger in the native group (Table 3). These findings proved the efficiency of the cleansing procedure.

SUVmax was higher in the bowel-preparation group than in the native group for small intestine and colon. The Mann–Whitney test showed that the difference in the small intestine was not significant (P = 0.088). In the colon, however, the difference was highly significant in all colonic segments except the sigmoid/rectum (Table 4). In the bowel-preparation group, most patients had the highest SUVmax in the ascending colon (15/26), followed by the sigmoid/rectum (8/26). In the native group, most patients had the highest SUVmax in the sigmoid/rectum (19/39), followed by the ascending colon (13/39).

The visual score analysis corresponded to the SUVmax measurements, with higher scores in the bowel-preparation group. Pearson χ² testing showed no significant difference in the small intestine (P = 0.685) and a highly significant difference in the colon (P < 0.001) (Table 5).

The comparison of diagnostic impairment from intestinal 18F-FDG accumulation showed slightly increased total impairment in the native group. Six patients (23%) in the bowel-preparation group and 11 (28%) in the native group had focal 18F-FDG accumulation in the colon (Fig. 1). One patient in the native group had 3 colonic segments with focal 18F-FDG activity. The Mann–Whitney test showed no statistically significant difference between the groups (P = 0.5).

### TABLE 1. Four-Step Scoring System for Areas with Highest Activity, Using Liver and Brain as Reference Sites

<table>
<thead>
<tr>
<th>Visual Score</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviation</td>
<td>&lt;lv</td>
<td>=lv</td>
<td>lv &gt; br</td>
<td>=br</td>
</tr>
</tbody>
</table>

### TABLE 2. Segmental Analysis of Stool Content in Colon

<table>
<thead>
<tr>
<th>Segment</th>
<th>Native group</th>
<th>Bowel-preparation group</th>
<th>P (Mann–Whitney)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending</td>
<td>31 (35)</td>
<td>12 (26)</td>
<td>0.001</td>
</tr>
<tr>
<td>Transverse</td>
<td>28 (38)</td>
<td>7 (26)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Descending</td>
<td>25 (36)</td>
<td>6 (26)</td>
<td>0.001</td>
</tr>
<tr>
<td>Sigmoid/rectum</td>
<td>29 (39)</td>
<td>6 (24)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Overall</td>
<td>113 (150)</td>
<td>31 (102)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

First number is segments containing visible amounts of stool. Number in parentheses is total segments evaluated.
DISCUSSION

The need to differentiate between physiologic and pathologic intestinal 18F-FDG uptake has been discussed since the very beginnings of PET, and suggestions on patient preparation (including bowel cleansing) have been made (6–8). To our knowledge, ours has been the first prospective, naturally randomized study to investigate the value of bowel preparation with a purging agent before PET/CT. Our findings—significantly higher 18F-FDG activity in the colon preparation with a purging agent before PET/CT. Our naturally randomized study to investigate the value of bowel preparation (including bowel cleansing) have been made the very beginnings of PET, and suggestions on patient

TABLE 3. Segmental Analysis of Average Colon Diameter

<table>
<thead>
<tr>
<th>Segment</th>
<th>Native group</th>
<th>Bowel-preparation group</th>
<th>P (Mann–Whitney)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending</td>
<td>3.5</td>
<td>2.9</td>
<td>0.022</td>
</tr>
<tr>
<td>Transverse</td>
<td>3</td>
<td>2.4</td>
<td>0.004</td>
</tr>
<tr>
<td>Descending</td>
<td>2.5</td>
<td>2.2</td>
<td>0.129</td>
</tr>
<tr>
<td>Sigmoid/rectum</td>
<td>3</td>
<td>2.5</td>
<td>0.036</td>
</tr>
</tbody>
</table>

particularly using anticholinergic muscle-relaxing drugs, was discussed to reduce 18F-FDG activity. However, previous results with anticholinergic drugs were rather controversial (7,8,11). Since such therapy is much more delicate than bowel preparation because of possible interaction with other drugs, a combination of both (laxative plus anticholinergic drug) did not seem useful. In addition, separating the effects of the 2 treatments would have been difficult.

Essentially all types of purging agents for bowel cleansing, senna-glycosides included, increase intestinal secretory activity either directly or indirectly (12). For sennosides, this effect seems to be achieved by activation of chloride channels in the bowel wall (13).

From a practical point of view and convenience for the patient, we selected a senna-glycoside which is easily applicable the day before the PET examination. All patients in the bowel-preparation group demonstrated significantly less stool in the colon, proving successful cleansing. However, the drug seemed to cause an activation/irritation of the colon clearly beyond a potential irritation caused by large amounts of stool, since significantly higher 18F-FDG uptake was demonstrated in the colon in the bowel-preparation group than in the native group. Interestingly, no difference was seen in the small bowel. Senna-induced colitis, causing inflammation and explaining the increased 18F-FDG activity, was not reported in our patients. Therefore, increased uptake can be related only to secretion or muscle activity. Muscle activity does not seem to be the cause of intestinal uptake, since motility reduction by the use of anticholinergic drugs could not demonstrate significant reduction in bowel uptake (11). It could be argued that secretion is probably also associated with increased bowel motility, which then causes increased 18F-FDG uptake. However, diffuse uptake in all colonic structures would be expected in such a case, which was not observed in our study. According to our results, which showed significantly increased intestinal 18F-FDG uptake in all colonic segments except the sigmoid/rectum, we postulate that activity in intestinal structures is caused mainly by 18F-FDG secretion.
into the bowel lumen. The nonsignificant difference in the 
in the rectum/sigmoid segment can be explained by the 
large number of patients in the native group with stool 
content, which seems also to cause increased secretion (10).

Interestingly, increased 18F-FDG uptake did not interfere 
with diagnostic quality. This was mainly due to the fact that 
increased 18F-FDG uptake observed in the bowel-prepara-
tion group was not focal but diffuse. Diffuse uptake is 
rarely related to malignant disease and therefore did not 
account for diagnostic impairment.

Regarding the limitations of this study, the natural 
randomization used to assign patients to the 2 groups could introduce a relevant selection bias (14). Natural randomi-
ization represented an easy approach with the greatest con-
venience for our patients. Statistical analysis of the 
patient population parameters showed no significant differ-
ence between the groups. If a selection bias had been 
introduced, we hypothesize that the bias would have been 
toward those patients with more severe disease choosing to 
to enter the control group. Severely ill patients in general have 
also had more therapies influencing bowel habits (e.g., 
chemotherapy, radiotherapy, or resection), causing various 
effects including inflammatory changes and diarrhea. We 
believe that these effects would have introduced an in-
creased intestinal 18F-FDG uptake, leading to a falsely high 
18F-FDG accumulation in the native group, even under-
estimating the irritating effects of bowel preparation.

CONCLUSION

Bowel preparation using a purging procedure increases 
18F-FDG activity in the large intestine and is therefore not 
useful before PET/CT.

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