Arteriography for Lower Gastrointestinal Hemorrhage
Role of Preceding Abdominal Computed Tomographic Angiogram in Diagnosis and Localization

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IMPORTANCE Optimizing the nature and sequence of diagnostic imaging when managing lower gastrointestinal hemorrhage may reduce subsequent morbidity and mortality.

OBJECTIVES To determine if preceding visceral arteriography with computed tomographic angiography (CTA) in acute lower gastrointestinal hemorrhage increases hemorrhage identification and localization and to determine if CTA was superior to nuclear scintigraphy when used as a pre-angiogram test.

DESIGN, SETTING, AND PARTICIPANTS Analysis was conducted of prospectively acquired data from an interventional radiology database and of individual electronic medical records from an academic tertiary medical center. On January 1, 2009, a new, evidence-based, institutional protocol that formally incorporated CTA to manage acute lower gastrointestinal hemorrhage was launched after multidisciplinary consultation. All records of patients who underwent visceral angiography (VA) for acute lower gastrointestinal hemorrhage from January 1, 2005, to December 31, 2012, were evaluated.

EXPOSURES Imaging, procedural, and operative details were abstracted from the medical records of all patients who underwent VA for lower gastrointestinal hemorrhage.

MAIN OUTCOMES AND MEASURES Visceral angiography results and efficacy were compared in patients before and after protocol implementation and compared based on which imaging method was used prior to angiography.

RESULTS A total of 161 angiographic procedures were performed during the study period (78 before and 83 after protocol implementation). Use of CTA increased from 3.8% to 50.6% following protocol implementation ($P < .001$). Preceding angiography with CTA resulted in similar angiography contrast administration (mean [SD] amount for CTA prior to VA, 135 [63] vs 160 [77] mL; $P = .18$) and fluoroscopy time (mean [SD], 26.3 [16.8] vs 32.2 [34.9] minutes; $P = .34$). Although nuclear scintigraphy and CTA had similar sensitivity and specificity, localization of hemorrhage site by CTA was more precise and consistent with angiography findings. As a pre-angiography test, compared with nuclear scintigraphy, CTA reduced overall the number of imaging studies required (mean [SD] number per patient admission, 2.1 [0.3] vs 2.5 [0.8]; $P = .005$) and resulted in administration of more overall contrast (mean [SD], 220 [80] vs 130 [70] mL; $P < .001$) without worsening renal function.

CONCLUSIONS AND RELEVANCE Preceding VA with a diagnostic study improves positive localization of the site of lower gastrointestinal hemorrhage compared with VA alone. Increasing the use of CTA for pre-angiography imaging may reduce overall imaging studies while appearing to increase positive yield at VA. Computed tomographic angiography can be used as part of a lower intestinal hemorrhage management algorithm and does not appear to worsen renal function despite the additional contrast load.

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Acute massive lower gastrointestinal hemorrhage (LGIH) is associated with significant mortality rates—4% for patients hospitalized for acute LGIH, rising to 23% for patients who develop LGIH while admitted to the hospital for other reasons. In the last 5 years, improvements in image acquisition, fidelity, and diagnostic interpretation, particularly in computed tomographic angiography (CTA), have introduced alternatives to the traditional workup and management of acute LGIH. It has thus become critical to develop a clear understanding of the correct sequencing of diagnostic studies and therapeutic interventions to optimize the management of patients with LGIH.

Endoscopic, angiographic, and surgical procedures may be used both to diagnose and treat LGIH; nuclear scintigraphy as used in nuclear bleeding scans (NBS) and, more recently, CTA may be used for diagnosis only. While imaging modalities that allow for therapeutic intervention may obviate the need for surgical intervention, they are not without risk. In addition, operative intervention for patients with bleeding without preoperative localizing imaging may result in resecting an intestinal segment that does not, in fact, contain the culprit site of hemorrhage.

Our institution recently incorporated the use of CTA into an evidence-based multidisciplinary protocol for the management of patients with LGIH (eFigure 1 in the Supplement). We sought to determine if adoption of this algorithm would result in increased procedural efficacy of visceral angiography (VA). We further hypothesized that CTA was superior to NBS when used prior to VA.

Methods

Institution and Institutional Protocol
An institutional protocol for management of LGIH was developed by the multispecialty Penn Center for Evidence-Based Practice and implemented at the Hospital of the University of Pennsylvania on January 1, 2009 (eFigure 1 in the Supplement). The hospital is an academic tertiary medical center that frequently cares for patients with acute LGIH. The emergency surgery service cares for patients with acute LGIH and is led by an in-house, board-certified, acute care surgeon and intensivist 24 hours a day, 7 days a week. Endoscopists, radiologists (CT and interventional radiology), and nuclear medicine specialists are available 24 hours a day, 7 days a week and can be called for assistance at any time, as necessary.

Patients who present with LGIH first undergo gastric lavage to rule out an upper GI hemorrhage and are actively resuscitated with crystalloid and blood products as appropriate throughout their hospital stay. Per the 2009 protocol (eFigure 1 in the Supplement), if patients are clinically stable, they are referred for colonoscopy; if not, they undergo CTA. Typically, a noncontrast abdomen and pelvis CT scan (120 kVp; 150 mAs; slice thickness, 3 mm) was followed by an arterial phase CT scan after injection of 100 mL of iodinated contrast and a fixed 35-second delay. Forty-five seconds later, a venous phase CT scan was performed (Figure 1).

Depending on CTA results and patient stability, interventional radiology and emergency surgery service faculty further discussed management, which may have included angiographic or surgical intervention.

Database Query
After obtaining approval from the University of Pennsylvania Office of Regulatory Affairs Institutional Review Board, the hospital interventional radiology database (Hi-IQ, Conexsys) was queried for all patients with LGIH who underwent VA between January 1, 2005, and December 31, 2012. Patient consent was not required as this was a retrospective review of medical records. The 8-year time period spanned the 4 years before and 4 years after implementation of the new institutional guideline. Keywords (eFigure 2 in the Supplement) that were found in the radiology patient record were used to identify all patients with LGIH evaluated by VA regardless of clinical service. These keywords identified 156 patients seen during 161 separate hospital admissions.

Extracting Information From the Electronic Medical Record
For all identified events, manual review of the electronic medical record was used to abstract demographic (sex, ethnicity, age, and body mass index [calculated as weight in kilograms divided by height in meters squared]), admission (hospital length of stay, discharge location), and laboratory data (minimum admission hemoglobin level as a proxy for severity of blood loss, maximum creatinine level increase from admission as a proxy for worsening renal function). Details about imaging studies (number and type of imaging studies performed [eg, NBS, CTA, and VA]), findings of those studies, amount of contrast used, fluoroscopy time, and therapeutic procedures (eg, embolization, endoscopic interventions [epinephrine injection, vessel clipping, or cautery]) were collected separately through direct review of individual records. Operative reports were queried for surgical interventions (colectomy, hemicolectomy, small-bowel resection, and oversewing of bleeding vessels within a lower GI viscus).

Data Analysis
Identified patients were first grouped as before or after guideline implementation depending on whether they were admitted before or after institution of the algorithm. A second analysis of outcomes was then conducted specifically comparing patients who underwent either a CTA or NBS only prior to VA. To determine the effect of first obtaining a CTA on VA parameters (fluoroscopic time, contrast administration, and rate of hemorrhage identification) and therapeutic intervention (rate of embolization), patients who underwent VA without another prior imaging modality (excluding endoscopy) were also compared with those who had a VA preceded by a CTA. Imaging modality sensitivity, specificity, positive predictive value, and negative predictive value for both NBS and CTA were determined using VA identification of the hemorrhage site as the criterion standard.

Statistical Analysis
The t test and the Pearson χ² test were used to compare groups as appropriate. Two-tailed statistical significance was set at P < .05.
Results

Use of Imaging Modalities Before and After Launching the Institutional Algorithm

Basic demographics were similar between groups before and after implementation of the protocol, as were hospital length of stay and proportion of patients discharged home (Table 1). Implementation of the protocol resulted in a marked increase in use of CTA compared with NBS for evaluation of patients with LGIH prior to VA (Table 1). Overall, use of NBS decreased by almost half while CTA use increased 15-fold ($P < .001$). Furthermore, patients undergoing only a single diagnostic imaging study (either NBS or CTA) prior to VA were much more likely to have their preliminary study be NBS before protocol implementation (94.2%) and CTA after protocol implementation (67.5%) ($P < .001$). Although CTA was added as an additional imaging option by the algorithm, the protocol did not result in a greater overall number of imaging modalities used.

Outcomes of Imaging Modalities After Launching the Institutional Algorithm

There were few differences in imaging results between the preguideline and postguideline implementation groups (Table 2). Laboratory parameters serving as surrogates of hemorrhage severity (minimum hemoglobin level) and worsening renal dysfunction (maximum percentage creatinine level increase) were similar in both groups. Nonetheless, patients received 30.5% more total intravenous contrast after guideline implementation ($P = .001$), although VA-specific contrast volume and fluoroscopy time remained constant between the groups.

Table 1. Patient Characteristics and Imaging Modalities Used

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Before Protocol Implementation (n = 78)</th>
<th>After Protocol Implementation (n = 83)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male, No. (%)</td>
<td>27/67 (40.3)</td>
<td>42/76 (55.3)</td>
<td>.09</td>
</tr>
<tr>
<td>White ethnicity, No. (%)</td>
<td>14/65 (21.5)</td>
<td>27/72 (37.5)</td>
<td>.06</td>
</tr>
<tr>
<td>Age on admission, mean (SD), y</td>
<td>68 (15)</td>
<td>70 (15)</td>
<td>.32</td>
</tr>
<tr>
<td>BMI, mean (SD)*</td>
<td>26.5 (7.6)</td>
<td>28.2 (6.8)</td>
<td>.14</td>
</tr>
<tr>
<td>Hospital length of stay, mean (SD), d</td>
<td>25 (68)</td>
<td>22 (58)</td>
<td>.72</td>
</tr>
<tr>
<td>Discharge to home, No. (%)</td>
<td>38/70 (54.3)</td>
<td>49/76 (64.5)</td>
<td>.24</td>
</tr>
<tr>
<td>No. of studies performed per patient admission, mean (SD)</td>
<td>2.3 (1.0)</td>
<td>2.4 (0.9)</td>
<td>.67</td>
</tr>
<tr>
<td>No. of VAs per patient admission, mean (SD)</td>
<td>1.2 (0.4)</td>
<td>1.1 (0.2)</td>
<td>.07</td>
</tr>
<tr>
<td>Patients undergoing at least one NBS, No. (%)</td>
<td>65 (83.3)</td>
<td>42 (50.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Patients undergoing at least one CTA, No. (%)</td>
<td>3 (3.8)</td>
<td>47 (56.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>No. of studies, mean (SD)</td>
<td>1.0 (0.7)</td>
<td>1.2 (0.7)</td>
<td>.15</td>
</tr>
<tr>
<td>Prior to first VA</td>
<td>0.3 (0.7)</td>
<td>0.2 (0.5)</td>
<td>.33</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CTA, computed tomographic arteriography; NBS, nuclear scintigraphy; VA, visceral arteriogram.

* Calculated as weight in kilograms divided by height in meters squared.
Diagnostic Value of CTA and NBS to Predict Positive VA Results

The specificity and sensitivity of NBS or CTA as pre-VA diagnostic tests were found to be similar (eTable in the Supplement). The greatest difference between both pre-VA tests was in the ability for each to specifically localize the LGIH. Nuclear scintigraphy with positive results usually localized the site of hemorrhage to a quadrant of the abdomen, while positive CTA results localized the hemorrhage to a specific segment of the colon or small bowel. Figure 2 demonstrates how localization of hemorrhage by CTA frequently matched localization by VA. Positive NBS results, on the other hand, were less anatomically related to where the source of hemorrhage was ultimately identified by VA (Figure 2).

Preempting VA With CTA

The subsequent analysis compared patients who underwent VA without prior tests with those who underwent CTA prior to VA (Table 3). As expected, patients receiving CTA underwent more studies and received more contrast overall, although the amount of contrast administered during VA was, again, similar in both groups. Nonetheless, patients who underwent CTA prior to VA displayed a lower mean increase in creatinine level than those who underwent VA only. Also, although the proportion of hemorrhage identification was similar in both groups, using CTA prior to VA more than doubled identification of the hemorrhage site (P < .001).

Effect of Preceding VA With an NBS

To determine which imaging modality best predicted subsequent VA findings, patients who underwent an NBS were compared with those who underwent CTA prior to VA (Table 3). The CTA group required fewer overall imaging studies but was associated with almost twice as many positive VA studies. Patients undergoing CTA received more contrast overall and had a longer fluoroscopy time, but these findings, at least in part, seemed related to the greater proportion of patients undergoing embolization in this group; among patients who underwent embolization, there were no differences in fluoroscopy time between the CTA and NBS groups.

General Costs of Imaging

Although no specific patient billing charges were obtained, the following are the costs per imaging study: CTA, $406.61; NBS, $381.57; VA, $1108.51; and VA plus embolization, $11,105.68. These figures represent average costs per study and varied minimally across the time of the analysis.

Discussion

We reviewed the 8-year experience of an academic center in patients who underwent VA as part of the management of acute LGIH. An evidence-based institutional guideline incorporating CTA was adopted midway through the study period and resulted in a marked shift toward the use of CTA rather than NBS as a pretest for VA. This shift did not change VA parameters (eg, fluoroscopy time, contrast volume given, or rate of successful embolization). As a pre-VA test, CTA resulted in administration of more overall contrast than with NBS, but without greater increases in renal dysfunction, while tending to reduce overall imaging studies used.

Colonoscopy is often the initial diagnostic modality used in cases in which upper GI hemorrhage has been excluded. However, active hemorrhage and the presence of stool in the unprepared bowel may render endoscopy incapable of localizing the source of hemorrhage despite extensive washing of the mucosal surface.3-4 For this reason and to exclude patients with chronic LGIHs, we did not include colonoscopies in our analyses. Nuclear scintigraphy is considered sensitive, is able to visualize bleeding rates of 0.1 to 0.3 mL/min, and also offers the ability to evaluate the entire GI tract for hemorrhage several hours after initiation of the test.5-7 While an NBS may not precisely localize the LGIH,8,9 if it is used prior to VA, an NBS may increase VA diagnostic yield10 and accuracy.11,12 Other reports suggest that an NBS has a poor predictive value for either VA or surgical interventions.13,14

Multidetector CTA is emerging as a promising, first-line, imaging technique to identify the location of intestinal hemorrhage. Studies on the use of CTA for massive LGIH have reported excellent accuracy,15-17 but it remains unknown how CTA compares with traditional LGIH imaging techniques. Animal studies have demonstrated that CTA may visualize rates of blood loss as low as 0.4 mL/min,18 and small clinical studies have shown that hemorrhage localization by CTA may be similar to that found with VA.19 Computed tomographic angiography offers the additional advantage of permitting patient triage for endovascular intervention.20

We evaluated whether CTA was superior to NBS in predicting VA results and therapeutic success. When viewed as a binary outcome (eg, positive or negative), the sensitivity, specificity, and accuracy of both were similar. However, when we compared each test’s ability to localize hemorrhage, CTA localized the site of hemorrhage more specifically than NBS. Prior studies have reported wide ranges of diagnostic accuracy for NBS, from 41% to 94%,10,11,13,14,21 suggesting wide variability in interpretation and among different populations. Computed tomographic angiography, on the other hand, has been shown to be highly accurate in the localization of LGIH in numerous studies.17,19-22 Marti et al7 calculated sensitivity, specificity, and accuracy of 100%, 96%, and 93%, respectively, for CTA compared with findings on colonoscopy, angiography, or surgical intervention. Identification of a target for VA could enable interventional radiologists to focus on imaging more distal colonic arterioles near the known site of hemorrhage, potentially reducing VA contrast dose and fluoroscopy time. Furthermore, imaging-directed segmental colectomy is associated with markedly lower mortality (13%-22%)3-5 and rebleeding rates (4%-14%)6-9 than blind segmental colectomy (mortality, up to 60%-9 and rebleeding, up to 75%).6-9 Although the rate of cessation of hemorrhage continues to improve (up to 70%-100%),5,10-12,15,16 rebleeding and major ischemic complications do still occur.10,12,15,16 Large contrast loads during VA may lead to contrast-induced nephropathy,17 and the test itself has limited sensitivity for patients with rates of blood loss estimated at less than 0.5 to 1.5 mL/min.18,19 Thus,
using an algorithm for LGIH that incorporates diagnostic studies with high negative predictive value prior to VA may minimize exposure to the risks of VA.

We did not observe reductions in VA fluoroscopy time or contrast requirements when CTA is used preemptively, which is likely owing to a relatively small sample size that does not

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**Table 2. Patient and Imaging Outcomes Before and After Protocol Implementation**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Protocol Implementation (n = 78)</th>
<th>After Protocol Implementation (n = 83)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhage found on any imaging, No. (%)</td>
<td>69 (88.5)</td>
<td>72 (86.7)</td>
<td>.81</td>
</tr>
<tr>
<td>Hemorrhage found on first VA, No. (%)</td>
<td>24 (30.8)</td>
<td>26 (31.3)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Embolization during first VA, No. (%)</td>
<td>21 (26.9)</td>
<td>24 (28.9)</td>
<td>.86</td>
</tr>
<tr>
<td>Minimum admission hemoglobin level, mean (SD), g/dL</td>
<td>6.9 (1.6)</td>
<td>7.0 (1.9)</td>
<td>.72</td>
</tr>
<tr>
<td>Maximum admission creatinine level increase, mean (SD), %</td>
<td>261 (354)</td>
<td>209 (152)</td>
<td>.22</td>
</tr>
<tr>
<td>Contrast given, mean (SD), mL</td>
<td>141 (69)</td>
<td>184 (94)</td>
<td>.001</td>
</tr>
<tr>
<td>VA only</td>
<td>129 (69)</td>
<td>138 (64)</td>
<td>.38</td>
</tr>
<tr>
<td>VA fluoroscopy time, mean (SD), min</td>
<td>23 (24)</td>
<td>23 (17)</td>
<td>.86</td>
</tr>
<tr>
<td>Intervention, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endoscopic</td>
<td>2 (2.6)</td>
<td>8 (9.6)</td>
<td>.09</td>
</tr>
<tr>
<td>Surgical</td>
<td>14 (17.9)</td>
<td>15 (18.1)</td>
<td>&gt;.99</td>
</tr>
</tbody>
</table>

Abbreviation: VA, visceral arteriogram.

SI conversion factor: To convert hemoglobin to grams per liter, multiply by 10.0.

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**Figure 2. Correlation Between Computed Tomographic Angiography (CTA), Nuclear Scintigraphy (NBS), and Visceral Angiography (VA)**

A

B

Correlation of anatomical localization of hemorrhage between CTA and VA (A) and between NBS and VA (B). The size of the black circles corresponds to the number of cases in each sample. The dashed lines separate small-bowel bleeding data points from colonic bleeding data points. LLQ indicates left lower quadrant; LUQ, left upper quadrant; RLQ, right lower quadrant; and RUQ, right upper quadrant.
permit capture of small differences in these parameters. Compared with patients who proceeded directly to VA, those who first underwent CTA required more overall imaging studies and received a greater cumulative intravenous contrast load. However, patients who underwent CTA experienced a lower creatinine level increase during hospitalization, suggesting that the additional contrast load was not associated with greater renal dysfunction.

Computed tomographic angiography can be used as an effective triage tool in LGIH. A meta-analysis of CTA for diagnosis of LGIH found values markedly different to ours for specificity (90% vs the 20% we observed)\(^2\); it is worth noting, however, that the included studies used a variety of reference standards (eg, colonoscopy, surgical intervention) for final localization of hemorrhage, making interpretation of these results difficult. In our study, we evaluated the ability of NBS and CTA to predict findings on VA and not as predictors of location of hemorrhage by any other methods. Negative CTA results in a hemodynamically stable patient have a high negative predictive value for the need for operative or angiographic intervention.\(^2\)\(^5\) As our study focused only on patients with LGIH who required VA, we did not evaluate patients who underwent CTA without VA and can therefore make no definitive statement on the utility of negative CTA results in managing LGIH. Nonetheless, transitioning from NBS to CTA to detect hemorrhage prior to VA did not worsen VA measures, nor did it negatively affect renal function despite the added contrast. These findings may have been related to continual improvement in microcatheters, embolization materials, and techniques used in superselective VA during the study period, all of which have resulted in greater VA success rates and reduced complication rates.\(^2\)\(^4\)\(^\text{-}^2\)\(^6\)

Of more importance was the comparison of NBS with CTA in predicting VA results. Patients who underwent only CTA prior to VA required fewer overall imaging studies and tended to more frequently have a source of hemorrhage identified and embolized on VA. Computed tomographic angiography has vastly preferable logistics compared with NBS. It is available at most institutions 24 hours a day, takes less than 3 minutes for acquisition of images, and is readily interpreted by most CT radiologists. On the other hand, an NBS requires hours of lead time for the radiotracer to be brought in (by taxi at our institution) and for blood to be withdrawn, mixed with the marker, and reinjected into the patient. Acquisition of NBS images occurs only after an additional 60 to 90 minutes, and the images are then read by a specialized nuclear medicine physician. Thus, our findings coupled with the logistical limitations of NBS suggest that CTA is an excellent and perhaps superior option as a pre-VA imaging study in patients with LGIH.

While this is an 8-year comparison of NBS with CTA in the prediction of VA findings in LGIH, it is a retrospective analysis and as such has important limitations. First, low sample sizes in some categories may have limited our ability to detect clinically relevant differences between groups. Second, the study did not evaluate for severity of hemorrhage and illness, and it is impossible to ascertain if all groups had similarly severe LGIHs. Despite this lack of evaluation, proxies for hemorrhage severity (eg, minimum hospitalization hemoglobin level) appeared similar between groups. Third, differences in serum creatinine levels are a crude measure of renal function. A better comparison would have used Acute Kidney Injury Network or RIFLE (risk, injury, failure, loss of kidney function, and end-stage kidney disease) acute kidney injury grade. Fourth, interventional radiology records often contained scant information about pre-procedure imaging findings, often making it impossible to assess the role that pre-procedure imaging played in guiding interventional radiology decisions during VA. Fifth, because this study is a pre-post analysis, findings are susceptible to bias by institutional and patient population changes that may have occurred in the institution during the study period but were unrelated to the protocol implementation. Finally, as we only evaluated patients who underwent VA, those with LGIH evaluated by other modalities without VA were not included and, as such, we cannot determine the specific utility of NBS or CTA in overall LGIH management.

### Conclusions

Preceding VA with a diagnostic study improves positive localization of the site of LGIH compared with VA alone. Furthermore, using CTA before VA does not appear to increase renal dysfunction compared with an NBS or VA only, even though
it resulted in a significant increase in contrast volume. Computed tomographic angiography was not only more effective than single-phase helical CT, it resulted in a significant increase in contrast volume. Computed tomographic angiography was not only more effective at localizing LGIH but also tended to result in fewer required tests and greater frequency of positive VA results. Further prospective studies will be needed to better characterize the role of CTA in the management of acute LGIH.

REFERENCES


