Comparative Evaluation of Dynamic Abdominal Sonography for Hernia and Computed Tomography for Characterization of Incisional Hernia

Rebeccah B. Baucom, MD; William C. Beck, MD; Sharon E. Phillips, MSPH; Michael D. Holzman, MD, MPH; Kenneth W. Sharp, MD; William H. Nealon, MD; Benjamin K. Poulose, MD, MPH

IMPORTANCE Previous work has demonstrated that dynamic abdominal sonography for hernia (DASH) is accurate for the diagnosis of incisional hernia. The usefulness of DASH for characterization of incisional hernia is unknown.

OBJECTIVE To determine whether DASH can be objectively used to characterize incisional hernias by measurement of mean surface area (MSA).

DESIGN, SETTING, AND PARTICIPANTS A prospective cohort study was conducted. A total of 109 adults with incisional hernia were enrolled between July 1, 2010, and March 1, 2012. Patients with a stoma, fistula, or soft-tissue infection were excluded.

INTERVENTIONS DASH was performed by a surgeon to determine the maximal transverse and craniocaudal dimensions of the incisional hernia. A separate surgeon, blinded to the DASH results, performed the same measurements using computed tomography (CT).

MAIN OUTCOMES AND MEASURES The MSA was calculated, and the difference in MSA by DASH and CT was compared using the Wilcoxon signed rank test. Subset analysis was performed with patients stratified into nonobese, obese, and morbidly obese groups. We hypothesized that there was no significant difference between MSA as measured by DASH compared with CT.

RESULTS A total of 109 patients were enrolled (mean age, 56 years; mean body mass index, 32.2 [calculated as weight in kilograms divided by height in meters squared]; and 67.0% women). The mean (SD) MSA measurements were similar between the modalities: DASH, 41.8 (67.5) cm² and CT, 44.6 (78.4) cm² (P = .82). The MSA measurements determined by DASH and CT were also similar for all groups when stratified by body mass index. There were 15 patients who had a hernia 10 cm or larger in transverse dimension. The mean body mass index of this group was 39.2, and the MSA measurements by DASH and CT were similar (P = .26).

CONCLUSIONS AND RELEVANCE DASH can be used to objectively characterize hernias by MSA, with accuracy demonstrated in the obese population and in patients whose hernias were very large (>10 cm in diameter). DASH offers the advantages of real-time imaging and no ionizing radiation and may obviate the need for the patient to schedule additional imaging appointments.
Incisional hernias are one of the most common problems faced by general surgeons; they occur in up to 28% of patients after initial laparotomy.1-4 Because of the large number of abdominal operations performed each year and the rate of hernia occurrence, nearly 350,000 repairs were performed in 2006, costing the United States an estimated $3.2 billion in periprocedural costs alone.3 Diagnosis and characterization of incisional hernias can be challenging, and few well-designed studies are available to guide surgeons through the process of diagnosis, characterization, management, and follow-up in these patients.

Currently, computed tomography (CT) is the accepted standard for the diagnosis and characterization of incisional hernias, especially in complex situations.4 However, the supine, static nature of the examination can result in undetected hernias that are apparent clinically. Physical examination often can detect large hernias, but in obese patients and those with small hernias, physical examination is unreliable. A previous study5 has shown that the sensitivity of physical examination is only 77% compared with CT for detection of incisional hernias. Certainly, the ability to characterize hernias by physical examination is affected by chronic incarceration, patient body habitus, and hernia location.

Dynamic abdominal sonography for hernia (DASH) has been described6 as a means to identify incisional hernias and as an attractive alternative to CT for detection of recurrence during long-term follow-up of patients. DASH has proven to be an accurate alternative to CT for diagnosis of incisional hernias, with a sensitivity and specificity of 98% and 88%, respectively. DASH also offers several advantages over CT including lack of exposure to ionizing radiation, real-time results available to the surgeon and patient, and, because of its dynamic nature, the potential for detection of hernias not readily apparent on CT. Although DASH is accurate for detection of hernias, it remains to be shown whether it also could be used to characterize hernias for the purpose of operative planning. The most common properties gleaned from a CT scan for operative planning appear to be the transverse dimensions of the hernia, hernia contents, and fascial boundaries. The purpose of the present study was to determine whether DASH can also be used for characterization of hernias by comparing the objective measurements of mean surface area (MSA) determined with CT and DASH.

### Methods

#### Design Overview

Patients were prospectively enrolled in the present study between July 1, 2010, and March 1, 2012, if they had an incisional hernia identified on either CT or ultrasonography. Baseline characteristics, including demographics, comorbidities, and surgical history, were recorded. As part of this study, DASH was performed and measurements of any hernias were taken in both the transverse and craniocaudal axes. Subsequently, CT images were reviewed and measurements were taken in the same axes by a separate surgeon. These measurements were used to calculate MSA for each modality assuming an ellipsoid shape of the incisional hernia. The ellipsoid shape was believed to provide the most accurate representation of most defects because most hernia defects are not perfect circles and are not rectangular. The median difference between the CT and DASH estimates of MSA was then compared. Because the transverse dimension is the most common descriptive measure used to characterize incisional hernia, the median difference of this metric was also compared between CT and DASH. This study was approved by the Vanderbilt Human Research Protection Program. At the time of enrollment, patients signed written informed consent for participation in the study. No financial compensation was provided.

#### Inclusion and Exclusion Criteria

Adults evaluated in a tertiary referral hospital’s general surgery clinic between 2010 and 2012 were invited to participate in a large hernia follow-up study using different modalities for detection and follow-up of incisional hernias. For the present study, patients were included if they had a history of any abdominal or pelvic operation (open or laparoscopic) with an incisional hernia of the anterior abdominal wall identified on CT or ultrasonography. Each patient was required to have a viewable CT scan of the abdomen and pelvis within 6 months of the enrollment date. Patients were excluded if any stoma, fistula, or active abdominal wall infection was present.

#### Hernia Characterization

The DASH examination was performed (W.C.B.) with the patient supine using a 12-MHz linear ultrasound probe. The examination began at the xiphoid, and scanning progressed inferiorly to the bony pelvis. The first pass focused on the linea alba, and the probe subsequently was repositioned laterally at the left costal margin. A series of craniocaudal passes was performed until the anterior superior iliac spine was reached, marking the lateral boundary of the examination. The sequence was then repeated on the right side. The DASH technique is described elsewhere.6

Once the hernia was identified during the DASH examination, the transverse and craniocaudal axes were measured to the nearest centimeter using real-time imaging. In cases in which both fascial edges were not visible on a single static image, the probe was positioned at the edge of the defect on one side, the skin was marked at the other edge of the probe, and the probe was repositioned. This process was repeated until the opposite fascial edge became visible, and the lengths of the probe were used in the calculation of the diameter. If multiple fascial defects were noted, the dimensions of the largest hernia were used for calculation of the MSA and comparison of the DASH and CT examinations. Computed tomography images of the same patient were then evaluated by a separate blinded surgeon (M.D.H., K.W.S., or B.K.P.) after the DASH examination, and criteria for hernia characterization were the same as those for the DASH examination. Transverse 3-mm cuts were visualized, and measurements of hernias were taken in 2 dimensions to calculate MSA.

#### Statistical Analysis

Baseline descriptive statistics were determined for the study population. The primary outcome measure was the MSA of the hernia. Paired data (ie, calculated MSA for both CT and DASH)
Results

One hundred nine patients from the prospective cohort had a hernia and were included in the study. Of these, 102 patients had a hernia noted with CT, and 107 patients had a hernia noted with DASH. There were 7 patients whose hernia was observed with DASH but not CT, and 2 patients whose hernias were observed with CT but not DASH. These 9 patients were excluded from the final analysis of the paired data. The population included 73 women (67.0%) and 36 men (33.0%) with a mean (SD) age of 55.9 (12.5) years and mean BMI of 32.2 (6.7). Thirty-seven patients (34.0%) had at least 1 prior hernia repair, and the mean number of prior hernia repairs was 1.9 (1.0). The comorbidities for this patient population are summarized in Table 1.

The MSA of hernias by CT was slightly larger than the MSA by DASH, and the difference was not significant (44.6 [78.4] vs 41.8 [67.5] cm²; P = .82). The transverse dimensions by CT and DASH were also very similar (5.20 [4.4] vs 5.17 [4.7] cm; P = .71). Figure 1 demonstrates the distribution of the difference in transverse dimension measured by DASH compared with CT. The mean difference between the measurements was 1.1 (1.6) cm. The difference between the 2 modalities was relatively small, with the largest difference being 11 cm.

Obese vs Nonobese

There were 14 patients in the morbidly obese group (BMI, ≥40.0), 49 patients in the obese group (BMI, 30.0-39.9), and 46 patients who were nonobese (BMI, <30.0). No patients qualified as superobese (BMI, ≥50.0). Demographics and comorbidities for each group are summarized in Table 1. The morbidly obese group had the highest proportion of patients with at least 1 prior hernia repair (7 of 14 patients [50.0%]). The mean MSA measurements between CT and DASH are summarized for each group in Table 2. Measurements by DASH were similar to those obtained by CT for all the groups, with no statistically significant difference detected.

Figure 2 summarizes the MSA measurements by DASH and CT for each BMI group. The median measurement determined by DASH and CT was similar for each BMI group, and the median hernia size determined by DASH and CT increased slightly for each BMI group. Although the range of hernia sizes increased with increasing BMI, the range was fairly consistent between DASH and CT in each group.

Finally, a subgroup analysis was performed only on patients whose hernias were 10 cm or larger in transverse dimension. This analysis was done to verify our findings in the population of patients with very large defects because many of the patients in the overall analysis had smaller defects. There were 15 patients with a hernia 10 cm or larger in transverse dimension (range, 10-21 cm). In this population, the mean number of prior hernia repairs was 1.9 (0.9), and most of the patients were obese (mean BMI, 39.2 [6.2]). The estimated MSA by CT was 189.4 (119.8) cm² and by DASH was 171.3 (92.6) cm² (P = .26).

Table 1. Demographics by BMI Groupa

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall (N = 109)</th>
<th>Nonobese (n = 46)</th>
<th>Obese (n = 49)</th>
<th>Morbidly Obese (n = 14)</th>
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<tr>
<td>Sex, No. (%)</td>
<td></td>
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<tr>
<td>Male</td>
<td>36 (32.0)</td>
<td>15 (32.6)</td>
<td>16 (32.6)</td>
<td>5 (35.7)</td>
</tr>
<tr>
<td>Female</td>
<td>73 (67.0)</td>
<td>31 (67.4)</td>
<td>33 (67.3)</td>
<td>9 (64.3)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>55.9 (12.5)</td>
<td>58.6 (14.0)</td>
<td>54.3 (10.9)</td>
<td>52.1 (11.3)</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>32.2 (6.7)</td>
<td>26.2 (2.9)</td>
<td>34.5 (2.9)</td>
<td>44.1 (2.8)</td>
</tr>
<tr>
<td>≥1 Prior hernia repair, No. (%)</td>
<td>37 (34.0)</td>
<td>14 (30.4)</td>
<td>15 (30.6)</td>
<td>7 (50.0)</td>
</tr>
<tr>
<td>No. of prior repairs, mean (SD)</td>
<td>1.9 (1.0)</td>
<td>1.9 (1.2)</td>
<td>2.0 (1.1)</td>
<td>1.6 (0.8)</td>
</tr>
<tr>
<td>Comorbidities, No. (%)</td>
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<tr>
<td>Diabetes mellitus</td>
<td>25 (22.9)</td>
<td>6 (13.0)</td>
<td>15 (30.6)</td>
<td>4 (28.6)</td>
</tr>
<tr>
<td>Smoking</td>
<td>27 (24.8)</td>
<td>9 (19.6)</td>
<td>12 (24.5)</td>
<td>6 (42.5)</td>
</tr>
<tr>
<td>Significant alcohol usea</td>
<td>5 (4.6)</td>
<td>2 (4.3)</td>
<td>2 (4.1)</td>
<td>1 (7.1)</td>
</tr>
<tr>
<td>COPD</td>
<td>5 (4.6)</td>
<td>1 (2.2)</td>
<td>1 (2.0)</td>
<td>3 (21.4)</td>
</tr>
<tr>
<td>Ascites</td>
<td>1 (0.9)</td>
<td>1 (2.2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Long-term corticosteroid use</td>
<td>3 (2.8)</td>
<td>1 (2.2)</td>
<td>1 (2.0)</td>
<td>1 (7.1)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease.

a BMI categories were nonobese (<30.0), obese (30.0-39.9), and morbidly obese (≥40.0) and were calculated as weight in kilograms divided by height in meters squared.
b Significant alcohol use was considered more than 2 drinks per day.
Discussion

This study demonstrates that DASH is not only accurate and reliable for detection of incisional hernias but can also be used for objective characterization of these hernias. This finding has significant implications for the overall plan of care for this large population of patients. DASH has previously been shown to be useful for detection of hernias, which was of particular interest for patient follow-up after hernia repair as well as monitoring for hernia recurrence. However, it was unclear whether DASH was useful for characterization of hernias for preoperative planning. The results of the present study suggest that characterization of the hernia, as determined by MSA and transverse diameter, is also possible using DASH.

In many patients, physical examination should suffice for the characterization of incisional hernias. This is especially true in thin patients with easily palpable and reducible fascial defects. However, with an increasingly obese population and in patients with multiple recurrent and chronically incarcerated hernias, supplemental information is often helpful for hernia characterization and preoperative planning. One study evaluated the accuracy of surgeon physical examination for simple detection of incisional hernias, and the sensitivity was only 77% compared with CT. Because of the limited sensitivity of surgeon physical examination, many patients in the present study did not have a hernia detected on physical examination; therefore, we did not compare measurements made by the surgeon on physical examination with those of DASH or CT. Gutiérrez de la Peña et al recommended that CT be performed as part of the regular postoperative assessment of symptomatic patients with a history of incisional hernia repair. In particular, they cited obesity and fibrosis from mesh implantation as factors that limited physical examination. The results of the present study show that real-time DASH examination in the clinical setting may obviate the need for CT prior to ventral hernia repair, decreasing cumulative radiation exposure, especially for patients who have had multiple hernia repairs.

Our study demonstrated that obesity was not a limiting factor in evaluation with DASH. We also noted that during performance of the DASH examination, previously placed mesh can be readily visualized and is hyperechoic, similar in appearance to a fascial plane. After only a few DASH examinations, it can be readily seen that the fascial planes of the abdominal wall have a remarkably similar appearance on ultrasonography and CT, suggesting that DASH is useful for assessment of the fascial planes for possible components separation. In addition, during the DASH examination, bowel can be readily visualized, particularly during peristalsis. Because the examination is conducted in a real-time setting, Valsalva maneuvers can be performed and hernia contents can be easily visualized as they enter the hernia sac, thereby detecting hernias that may not be apparent on CT. This maneuver also may be useful for determining whether the contents appear to be incarcerated. Structures that are not well appreciated on DASH examination include omentum and deeper structures in the abdominal cavity and retroperitoneum. Although these characteristics are not easily evaluated objectively and the present study was not designed for the purpose of evaluating these characteristics, our experience with DASH suggests that surgeon-performed ultrasonographic examination will allow evaluation of many more...
Evaluation of Ultrasonography vs Computed Tomography

Table 2. MSA Results by BMI Group

<table>
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<tr>
<th>BMI Groupa</th>
<th>Mean (SD)</th>
<th>P Value</th>
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</thead>
<tbody>
<tr>
<td>Nonobese (n = 46)</td>
<td>19.3 (20.3)</td>
<td>21.1 (27.1)</td>
</tr>
<tr>
<td>Obese (n = 49)</td>
<td>47.5 (69.5)</td>
<td>43.9 (59.4)</td>
</tr>
<tr>
<td>Morbidly obese (n = 14)</td>
<td>108.2 (151.8)</td>
<td>107.4 (131.4)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CT, computed tomography; DASH, dynamic abdominal sonography for hernia; MSA, mean surface area.

a BMI categories were nonobese (<30.0), obese (30.0-39.9), and morbidly obese (≥40.0) and were calculated as weight in kilograms divided by height in meters squared.

Aspects of the hernia as the surgeon gains more experience with the technique. In an era of cost containment and payment bundling for disease-based problems, DASH offers an attractive means of ventral hernia evaluation compared with the expense of CT imaging.

Some training in the use of ultrasonography is required for the DASH technique. However, when used for focused examinations, surgeon-performed ultrasonography has been shown to be adequate compared with ultrasonography performed and interpreted by radiologists. The surgeons in the present study used the Ultrasound for Surgeons Basic Course offered by the American College of Surgeons to gain basic knowledge of ultrasonographic technique and its applications. DASH also has been shown to be readily reproducible between surgeons without a steep learning curve. In our experience, surgeons became facile with DASH after approximately 10 examinations. DASH is a natural addition to the flow of the clinic and can be easily incorporated as part of the physical examination. Just as the Focused Assessment With Sonography for Trauma examination and thyroid ultrasonography are performed by surgeons and are billable examinations, the DASH examination is a billable service.

Several limitations are apparent in this study. First, full characterization of incisional hernia includes information beyond simple 2-dimensional measurements. It is well recognized that preoperative planning requires a careful evaluation of the hernia in relationship to fascial boundaries, bony structures, and other visera. In clinical practice, we have found that bony relationships, previously placed mesh, fascial planes, and abdominal wall anatomy are sufficiently evaluated by a combination of physical examination and DASH. We chose 2-dimensional measurements of incisional hernia to facilitate an objective comparison of DASH and CT and because incisional hernias are most often characterized by size. The precise clinical scenarios in which CT would need to be completed in addition to or in lieu of the DASH examination will be determined after DASH has become widely adapted to clinical practice.

A second limitation of this study is the anticipated variability in the performance of an ultrasonography-based modality among examiners. This limitation is a reasonable concern because the subjectivity of ultrasonography can make accurate characterization of incisional hernia potentially variable among examiners. Previous work measuring interrater reliability of the DASH examination confirmed that the results are reproducible for the detection of incisional hernias. We did not perform more extensive interrater reliability testing comparing the accuracy of measurements between examiners.

A third limitation of DASH compared with CT is that the examination does not fully evaluate the abdominal cavity and retroperitoneum. Although the hernia size and other characteristics appear to be accurately evaluated during the DASH examination, other potential intra-abdominal abnormalities would be missed with DASH. Even though the probability of finding other abnormalities on CT in this setting is unknown, incidental findings of significance have been discovered on CT evaluation.

Conclusions

In addition to its application for clinical follow-up of patients who have undergone incisional hernia repair, DASH can be used preoperatively to accurately characterize incisional hernias. Based on the results of the present study, consideration should be given to the use of DASH for diagnosis and characterization of incisional hernias in patients who are evaluated by a surgeon. This procedure reduces radiation exposure, allows for real-time diagnostics, and does not sacrifice accuracy. Integration of the DASH examination into the flow of a clinic visit is easily accomplished, and surgeons should consider making this procedure a part of their routine practice.
Potential for Ultrasonography to Reduce the Cost and Cumulative Radiation Dose in Routine Incisional Hernias

Matthew I. Goldblatt, MD

As our population ages, becomes more obese, continues to smoke, and develops type 2 diabetes mellitus, incisional hernias and recurrences are becoming more prevalent. Management of these complex hernias has become so challenging that the American Hernia Society has become one of the fastest growing surgical specialty organizations. As surgeons become more skilled at treating incisional hernias, the need to diagnose recurrences and characterize the abdominal wall of an affected patient has become increasingly important. Computed tomography (CT) is the criterion standard for evaluating the abdominal wall, but Baucom et al have shown that ultrasonography can be used to characterize the dimensions of the hernia defects as effectively as CT.

The advantage of CT for a hernia is that it shows the layers of the abdomen in a format with which most surgeons are familiar. Sagittal and coronal reconstructions aid in preoperative planning, particularly in recurrent hernia operations. However, if a patient has had multiple abdominal operations and recurrent hernias, the number of lifetime CTs per patient is often in the double digits. In addition to multiple CTs increasing the cost of treating incisional hernias, it has been hypothesized that the cumulative radiation could contribute to abdominal cancers. The level of ionizing radiation during a single multiphase CT of the abdomen-pelvis has been estimated to increase the lifetime risk to 4 cancers per 1000 patients.

Although the risk for additional cancers associated with modern imaging is up for debate, reducing the number of CT scans will help decrease both the radiation exposure and the cost of treating abdominal wall hernias. Ultrasonography may not completely replace CT, particularly in more complex hernias; however, it can be useful in the diagnosis and measurement of a suspected hernia and may reduce the number of CTs that are obtained.

REFERENCES