Eccentric stent graft compression: An indicator of insecure proximal fixation of aortic stent graft

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Purpose: The purpose of this study was to determine whether radiographically demonstrated proximal stent graft contour can be used as a marker for security of proximal neck fixation after endovascular aneurysm repair.

Methods: Stent graft structure was examined in 100 consecutive patients with abdominal aortic aneurysms who were treated with the stent graft. Stent graft integrity, stent contour, angulation, compression, and position were assessed by plain abdominal radiography, and the results were correlated with contrast computed tomography (CT) scanning, clinical findings, and outcomes. Repeated imaging was carried out during follow-up of 3 to 38 (mean, 12) months.

Results: Stent graft repair was successful in all 100 patients. No stent fractures were identified. Concentric compression of the proximal portion of the stent graft was visible in 69% of patients and reflected deliberate oversizing of the stent graft at the time of implantation. In 5% of patients, a short eccentric compression deformity of the proximal stent was observed. This finding was associated with an increased risk of stent graft migration (P < .01) and with an increased risk for development of a late proximal (type I) endoleak (P < .01). Compared with CT scanning, abdominal radiography was less useful for assessment of short distances of migration (sensitivity 67%; specificity 79%). However, they provided better definition of the stent graft in relation to bony landmarks and better visualization of aortic calcification than CT with three-dimensional reconstruction.

Conclusion: Plain abdominal radiographs are important in the postoperative evaluation of patients with aortic stent grafts. They allow for more precise evaluation of the structural elements of the stent graft than CT scanning and may disclose inadequate proximal fixation by demonstration of an eccentric compression deformity. They are less useful for assessment of migration. (J Vasc Surg 2001;33:481-7.)

Endovascular devices for the treatment of aortic aneurysms are generally constructed by use of two structural components: metallic stents and fabric grafts. Self-expanding or balloon-expandable metallic stents fix the device to the aortic wall and the fabric graft provides a conduit that is impervious to blood. The effectiveness of stent grafts in excluding aortic aneurysms from the circulation is dependent on the integrity of the metallic stent framework. The AneuRx stent graft (Medtronic Ave, Inc, Santa Rosa, Calif) consists of a woven polyester fabric graft with a self-expanding nitinol exoskeleton. Fixation of the stent graft is dependent on radial expansion against the normal infrarenal aortic neck, as well as iliac fixation and longitudinal columnar support. The stent graft is usually oversized 10% to 20% in relation to the proximal aortic neck, resulting in slight compression of the stent bodies within the infrarenal neck. We hypothesized that the contour of this compression deformity may provide clues regarding the adequacy of proximal stent graft fixation. We reviewed 100 patients treated with the AneuRx stent graft and examined the contour of the stent graft within the infrarenal neck to identify markers that could be used to determine the adequacy of proximal fixation.

METHODS

We reviewed abdominal radiograms of 100 consecutive patients who underwent endovascular repair of abdominal aortic aneurysms with the AneuRx stent graft at Stanford University Medical Center from 1996 to 1999. All patients were evaluated with postprocedure contrast CT scans, duplex ultrasound scanning, as well as with plain abdominal radiograms before hospital discharge, at 1 month, 6 months, and 12 months, and at yearly intervals thereafter. Routine abdominal radiograms were obtained.
with patients in the anteroposterior projection. Additional imaging studies were obtained if clinically indicated.

All assessments were done by two independent observers, and, in all cases of disagreement, findings were jointly reviewed, and consensus was reached. Structural integrity of the stent framework was reviewed. The structure of the proximal portion of the stent graft was assessed on the abdominal radiographs. Stent graft compression was defined as concentric reduction of stent graft diameter within the proximal neck compared with the immediately adjacent portion of the stent graft. Configuration of the stent graft within the neck was categorized as straight, angulated, barrel-shaped, hourglass, or eccentric compression (Fig 1).

Length measurements were normalized to the size of a single stent unit (“diamond”), which is known to be 9 mm in length, to facilitate comparison between radiographs and appreciation of actual sizes. The degree of calcification of the aortic wall in the region of the neck was noted and categorized as absent, moderate, or severe. Sequential abdominal radiographs for each patient were compared to determine changes in structure and to identify stent graft migration. For assessment of migration, serial abdominal radiographs were categorized as inadequate if differences in projection angle precluded comparison of stent graft position between films. Migration was defined as an axial change of 4 mm or more in the position of the stent graft.

Spiral preoperative CT scans of all patients were reviewed for length, diameter, angulation, and calcification of the infrarenal neck. Serial postoperative spiral CT scans were reviewed for evidence of stent graft migration and for serial measurements of infrarenal neck diameter.

The proximal segment of the endograft was evaluated on three-dimensional renderings of contrast spiral CT scans and compared with plain abdominal radiographs. All patients were evaluated for early or late endoleak and other stent graft-related events.

Statistical analysis was carried out with $\chi^2$ analysis and the Student $t$ test. Results were considered to be significant if $P$ was less than .05.

RESULTS

Stent graft size on the abdominal radiographs was highly variable because of differences in radiographic magnification. The apparent size of a single stent graft “diamond” (9 mm) varied from 6 to 18 mm (mean, 9.3 ± 2.4 mm). The proximal portion of the stent graft was com-

Fig 1. Proximal stent graft configurations.

<table>
<thead>
<tr>
<th>Migration</th>
<th>No migration</th>
<th>Abdominal radiographs inadequate</th>
<th>Abdominal radiographs adequate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration by CT</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>No migration by CT</td>
<td>17</td>
<td>2</td>
<td>72</td>
<td>91</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>8</td>
<td>74</td>
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Compared with CT as the gold standard, abdominal radiographs had a sensitivity of 67%, a specificity of 79%, a positive predictive value of 75%, and a negative predictive value of 97%.
pressed by more than 5% in 69% of patients. The degree of compression ranged from 5% to 30% (mean, 13% ± 9%), and the length of the compressed segment was 23 ± 8 mm. The configuration of the proximal stent graft was straight in 53%, angulated in 21%, barrel shaped or hourglass shaped in 21%, and compressed eccentrically in 5% of patients (Fig 1).Calcification of the aortic wall in the region of the neck was absent in 32%, moderate in 50%, and severe in 18% of patients.

During a follow-up period of 3 to 38 months (mean, 12 months), no instances of stent fracture or disruption of the stent graft were observed. In comparing sequential abdominal radiographs for assessment of migration, 18% of films were deemed inadequate because of a marked difference in projection. In 74%, no change in the position of the stent graft was observed, and in 8%, stent graft migration was identified on abdominal radiographs. Review of spiral CT scans confirmed migration of a short distance (4-11 mm) in six of eight cases, as well as in three others, yielding a CT-detected migration rate of 9% (Table I). Comparative path length measurements from renal artery origins to the top of the stent graft on three-dimensional data sets were performed on two patients and confirmed migration of the stent grafts.

Among the various proximal graft configurations, only eccentric proximal compression had prognostic significance. Eccentric compression was a marker of increased risk of subsequent stent graft migration (P < .01), whereas length of the proximal neck, its diameter, and its angulation as measured on preoperative CT scanning were not. Among five patients with eccentric compression of the proximal stent graft, four patients (80%) demonstrated migration of the stent graft on CT scanning (axial distance of 4-10 mm) during a follow-up of 19 to 33 months. In contrast, only five (5%) of the 95 patients without eccentric compression (P < .01) showed any stent graft migration. In three of the latter patients, migration was due to a markedly low placement of the stent graft in the aneurysm neck. In the fourth patient, migration was due to a short proximal neck, and the fifth patient had insufficient oversizing of the implanted stent graft. Infra renal neck diameter on serial CT scans on all of these patients with migration remained unchanged.

Two of the five patients with eccentric compression (40%) had development of a new, late proximal endoleak at 8 and 12 months. In contrast, a new endoleak occurred in only one (1%) of the 95 patients without eccentric compression (P < .01), and this occurred 30 months after implantation. All three endoleaks were successfully sealed with proximal extender cuffs, and all patients have done well (Figs 2 and 3). In the remaining three of the five patients with eccentric compression, although they did not have development of endoleaks or sustain any adverse clinical events during their 19 to 33 months of follow-up, two had evidence of stent graft migration. The first patient is 33 months after endovascular repair, and his stent graft has migrated 7 mm, but he remains symptom free, without an endoleak, and aneurysm diameter has decreased by 4 mm (Fig 4). Serial abdominal radiographs demonstrated progressive distal migration of the stent graft. Because of the tenuous proximal fixation of the stent graft (Fig 4, C), a prophylactic insertion of proximal extender cuff was recommended. Thus far the patient has declined this recommendation and is being monitored closely. The second patient is 30 months after implantation and has had a 4-mm migration of his stent graft without an endoleak, a stable aneurysm size, and no clinical symptoms. The third patient is doing well 19 months after implantation without any evidence of migration or endoleak and a decrease in aneurysm diameter by 18 mm.

Eccentric compression was not associated with an increased risk of persistent endoleak (beyond 1 month) or the need for secondary interventions. There was no difference in aneurysm diameter changes between patients with and those without eccentric compression (Table II).

Moderate or severe calcification in the region of the neck was seen in four of the five patients with eccentric compression and served to demonstrate the short segment apposition of the aortic wall to the stent graft. Although abdominal radiographs are not the optimal method for evaluation of aortic calcification, the presence of the aortic stent graft localizes the aortic neck and greatly facilitates this type assessment. This short segment of fixation was related to a low deployment in one patient and to a short neck (< 15 mm) in four patients, although neck length or oversizing per se were not significantly associated with this finding. Angulation of the proximal neck was not significantly associated with eccentric compression, but in one patient the neck had an angulation of 60 degrees. We did not otherwise systematically categorize configuration of the infrarenal aortic neck on preoperative CT scanning on these patients. However, examination of the configuration of the neck in patients with eccentric compression deformity did not disclose anything out of the ordinary except for the angulation mentioned.

Configuration of the proximal stent graft is not easily appreciated on cross-sectional CT. Postoperative three-dimensional renderings of spiral CT angiograms were performed in 55 patients. These demonstrated the general configuration of the stent graft but did not depict the stent structure as clearly as plain abdominal radiographs. Furthermore, they failed to demonstrate the relationship of the stent graft to the bony structures and aortic calcifications.

DISCUSSION

We found that eccentric compression deformity of the proximal portion of the stent graft is visible on postoperative plain abdominal radiographs in 5% of patients undergoing endovascular aneurysm repair with the AneuRx stent graft. This radiographic finding was associated with an increased risk of subsequent stent graft migration and the delayed appearance of a new proximal endoleak. No patient in this series experienced aneurysm rupture, but three patients had development of late, acute endoleaks and underwent successful endovascular treatment with proximal extender cuffs to prevent potential rupture.

We reviewed the abdominal radiographs and spiral CT scans of two patients treated with AneuRx stent grafts at other centers who have experienced aneurysm ruptures. Both of these patients demonstrated eccentric compression deformity of the stent graft on the postoperative abdominal radiographs. One patient, after an apparently
Fig 4. A, Postoperative abdominal radiograph shows eccentric compression of stent graft. B, Abdominal radiograph at 13 months. C, Abdominal radiograph at 25 months. Stent graft has migrated 7 mm to low position in aortic neck. Placement of proximal extender cuff was recommended, but patient declined.
Successful endovascular repair with complete exclusion of the aneurysm, had development of an acute proximal endoleak and had rupture at 14 months. This patient underwent a successful open repair. Similarly, the second patient who had proximal eccentric compression deformity had no endoleak or clinical symptoms and had rupture at 9 months after implantation. Proximal endoleak and poor fixation were found at the time of open repair. Patients with eccentric compression are at increased risk for stent graft migration. The underlying mechanism of this event appears to be the result of inadequate fixation of the stent graft at the proximal neck because of a short segment of aorta-to-stent graft apposition. No single feature of the neck was found to predict eccentric deformity, but it appears to result from a combination of a short neck and imperfect deployment. The eccentric stent graft configuration may result in an uneven radial force and an inconsistent frictional force on the aortic wall, which is required for durable stent graft fixation. Thus, eccentric compression visible on plain abdominal radiographs is a marker of insecure proximal fixation and may help identify patients who are at increased risk of aneurysm rupture.

Aortic calcifications on postoperative abdominal radiographs can help define the spatial relationships between the stent graft and the aortic neck, especially in cases of short fixation lengths related to low placement of the stent graft or to a short neck. In addition, calcification of the aortic neck may play a causative role by its reduced compliance and deformability and thus prevent full expansion and apposition of the stent graft to the aortic wall.

Stent graft migration has been recognized as a potential problem with aortic stent grafts. Thus far, the factors associated with its occurrence have not been clarified. Some stent grafts have hooks or barbs, but good apposition of a sufficiently long segment should be effective in securing adequate fixation. Progressive dilation of the neck may be a factor in stent graft migration, but we did not find it, and in those cases with eccentric compression, fixation was inadequate from the beginning. The relatively long time interval from the initial graft placement until the time when migration occurred may be related to the longitudinal columnar support of the AneuRx device. Such columnar support may temporarily prevent distal dislodgment in spite of suboptimal proximal fixation, as a result of secure fixation to the iliac arteries.

Although abdominal radiographs are useful for assessing the configuration of the stent graft, measurement of migration is limited by differences in projection angle and magnification in serial studies. The most accurate technique for assessment of migration is comparative path length from renal artery orifice to the top of the stent graft on serial three-dimensional CT reconstructions, as performed in two cases here. However, this technique is too labor-intensive for routine clinical application, and spiral CT provides solid, reproducible results.

We conclude that plain abdominal radiographs are important for follow-up after endovascular abdominal aortic aneurysm repair. Careful inspection of proximal stent graft structure and recognition of eccentric compression deformity on the postoperative abdominal radiograph may indicate inadequate fixation with an increased risk of migration and late, acute proximal endoleaks. This should prompt closer follow-up and consideration for prophylactic intervention. As a corollary, it is important to note that the mere absence of an endoleak is not a good predictor of a favorable long-term outcome.

### REFERENCES