Lateral Movement of Endografts Within the Aneurysm Sac Is an Indicator of Stent-Graft Instability

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Purpose: To determine if lateral movement of an aortic endograft 1 year following endovascular abdominal aortic aneurysm (AAA) repair is an indicator of endograft instability and can serve as a predictor of late adverse events.

Methods: The records of 60 high-risk AAA patients (52 men, 8 women; mean age 74 years) who were treated with infrarenal (n=38) or suprarenal (n=22) endografts and had serial computed tomograms (CT) over ≥12 months were analyzed. Postimplantation and 1-year CT scans were compared, and changes in endograft position within the aneurysm sac [lateral movement (LM) versus no lateral movement (NM)] were measured using a vertebral body reference point. Longitudinal endograft movement was measured with respect to the superior mesenteric artery along the aortic centerline axis. Long-term adverse event rates (endoleaks, secondary procedures, conversion, rupture, and death) were assessed.

Results: One year after endograft implantation, LM ≥5 mm was present in 16 (27%) patients; 44 (73%) endografts demonstrated no lateral movement. LM patients had larger aneurysms (6.5±1.5 versus 5.6±0.9 cm, p=0.02) and a longer endograft–to–hypogastric artery length (p=0.01) than NM patients. There were no significant differences between patients treated with infrarenal and suprarenal endografts. At 1 year, longitudinal migration ≥10 mm occurred in 5 (31%) of the LM patients versus 2 (5%) in the NM cohort (p<0.0001). There were no significant differences in adverse event rates between LM and NM at 1 year. However, during long-term follow-up (mean 54±26 months, range 12–102), 8 (50%) LM patients developed a type I endoleak versus 8 (18%) NM patients (p=0.02), and 12 (75%) LM patients required a secondary procedure versus 9 (20%) NM patients (p=0.0002). One (6%) LM patient experienced aneurysm rupture and 2 (13%) other LM patients underwent conversion to open repair.

Conclusion: Lateral endograft movement within the aneurysm sac at 1 year is associated with increased risk of late adverse events and was at least as good a predictor of these complications as was longitudinal migration.

Key words: abdominal aortic aneurysm, endovascular aneurysm repair, stent-graft, lateral movement, longitudinal movement, adverse events, migration, type I endoleak, secondary procedures, rupture, conversion

The annual ISES Endovascular Fellows Research Awards Competition held on February 12, 2008, at International Congress XXI on Endovascular Interventions (Scottsdale, Arizona, USA) evaluated participants on both their oral and written presentations. ISES congratulates the 2008 winners.

Christopher Zarins is a consultant to Medtronic Vascular, manufacturer of the endografts used in this study. The other authors have no commercial, proprietary, or financial interest in any products or companies described in this article.

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Positional stability of aortic endografts is important for the long-term durability of endovascular aortic aneurysm repair (EVAR).\(^1\)\(^–\)\(^3\) Longitudinal migration of endografts may lead to loss of fixation and the development of type I endoleaks, potentially exposing the patient to the risk of aneurysm rupture.\(^4\)\(^–\)\(^6\) However, accurate determination of endograft migration on routine cross-sectional axial computed tomograms (CT) can be difficult, and some patients may require secondary intervention in the absence of obvious migration.\(^7\) Changes in endograft position in the mid-portion of the aneurysm sac can be readily seen on serial cross-sectional CT scans or duplex ultrasound. Until now, such changes have been briefly described only in geometric analyses\(^8\)\(^,\)\(^9\) but have not been closely studied or monitored as part of the routine endograft surveillance. Accordingly, the purpose of this study was twofold: (1) to design a simple and reproducible method to quantitate changes in the position of the endograft on serial cross-sectional CT scans and (2) to test the hypothesis that lateral movement of the endograft within the aneurysm sac is a predictor of long-term endograft instability.

**METHODS**

**Patient Population**

Patients with abdominal aortic aneurysms (AAA) who underwent EVAR at our institution from 1997 to 2004 and were prospectively followed with serial imaging and clinical follow-up were considered for this study. Informed consent was obtained from each patient prior to surgery, and all patient follow-up protocols, including imaging, were approved by the Institutional Review Board. This retrospective analysis began with review of imaging and clinical data for 60 EVAR patients (52 men, 8 women; mean age 74 years) who had baseline, postoperative, and 1-year follow-up CT studies performed at our institution with online datasets that were suitable for quantitative 3-dimensional (3D) image analysis. Thirty-eight patients had infrarenal endograft implantation (AneuRx stent-graft; Medtronic Vascular, Santa Rosa, CA, USA), while 22 patients were treated with a suprarenal endograft (Talent stent-graft; Medtronic Vascular).

**Image Analysis**

Postimplantation and 1-year follow-up CT scans were evaluated using GE Centricity software (GE Healthcare, Chalfont St Giles, UK). The position of the endograft within the aneurysm sac was measured using a vertebral body reference point. The axial CT slice corresponding to the maximum aneurysm diameter at the midpoint between the inferior border of the superior mesenteric artery (SMA) orifice and the aortic bifurcation was selected for image analysis; the same anatomical level was selected on the 1-year follow-up CT by matching bony landmarks on the vertebral bodies. Lateral endograft movement was defined as a $\geq 5\text{-mm}$ change in the distance between the mid-portion of the stent-graft and the anterior portion of the vertebral body at 1 year (Fig. 1). All quantitative imaging measurements were obtained by a single investigator who was not involved in the clinical care of the patients and was blinded to their clinical outcomes. Patients exhibiting $\geq 5\text{-mm}$ lateral endograft movement were assigned to the “lateral movement” (LM) patient group; those exhibiting $<5\text{-mm}$ lateral movement were placed in the “no lateral movement” (NM) group.

Preoperative aneurysm characteristics, as well as postoperative iliac fixation length and the distance from the distal endograft to the hypogastric arteries, were measured using quantitative 3D image analysis, as described previously.\(^7\) Downward displacement of the proximal portion of the endograft (i.e., longitudinal migration) referred to any change in centerline distance between the inferior SMA orifice and the proximal portion of the stent-graft at 1 year. Angulation of the device was determined by measuring the distance in millimeters from the top of the endograft to the level of the complete ring (Fig. 1).

**Clinical Analysis**

Adverse clinical outcomes were recorded in all patients at 1 year and at last available
follow-up. Outcome measures included need for secondary intervention (including proximal or distal extender cuff placement or coil embolization of endoleak), type I endoleak (defined as persisting at 1 year or necessitating a secondary procedure at any point), aneurysm rupture, surgical conversion, and aneurysm-related death.

Statistical Analysis

Results are expressed as the mean $\pm$ standard deviation for continuous variables and as counts (percentages) for binary variables. Comparison of aneurysm characteristics, baseline demographics, and outcomes for the 2 patient groups was performed using Student $t$ tests for continuous variables and 2-tailed Fisher exact tests for categorical variables. Predictors of lateral movement were assessed with an analysis of variance (ANOVA). P $<$ 0.05 was considered significant. All statistical analyses were performed using JMP 6 software (2005; SAS Institute Inc., Cary, NC, USA).
RESULTS

Of the 60 patients included in the study, 16 (27%) endografts exhibited ≥5-mm lateral movement (LM group, Fig. 2) at 1 year, whereas 44 (73%) exhibited <5-mm lateral movement (NM group). There were no significant differences in age, gender distribution, preoperative comorbidities, or length of follow-up between the groups (Table 1).

Baseline

Preoperative CT scans revealed no significant differences in infrarenal aortic neck length or diameter. However, patients in the LM group had a larger preoperative aneurysm diameter compared to NM (6.5±1.5 versus 5.6±0.9 cm, p=0.02). Postimplantation CT scans revealed no significant differences in proximal aortic or distal iliac endograft fixation length between LM and NM. However, the LM group had a greater distance from the distal end of the endograft to the hypogastric arteries (16±8 versus 10±10 mm, p=0.01). The LM group also had slightly greater angulation of the proximal portion of the endograft neck on the postimplantation CT scan, although this difference only approached significance (11±4 versus 9±4 mm, p=0.06). The type of device used (infrarenal or suprarenal) did not have a significant effect on the development of LM.

Figure 2 ◆ Examples of post-procedure (A1–D1) and 1-year (A2–D2) CT scans. (A) No significant movement of the endograft at 1 year in a 5.3-cm aneurysm. (B) Ten-mm movement of the endograft at 1 year in a 6.4-cm aneurysm. (C) Sixteen-mm movement at 1 year in a 7.1-cm aneurysm. (D) Sixteen-mm movement at 1 year in a 7.8-cm aneurysm.
One Year

In the LM group, mean lateral movement of the endograft was 9 ± 6 mm compared to 2 ± 1 mm in the NM group (p < 0.0001, Table 2). The LM group also had significantly more longitudinal endograft migration (8 ± 6 versus 4 ± 3 mm, p = 0.003). The aneurysm sacs decreased equally in both groups at 1 year, with average aneurysm size remaining significantly larger in the LM group. Longitudinal endograft migration ≥ 10 mm was detected in 5 (31%) of the LM patients but in only 3 (7%) of the NM patients (p < 0.0001). LM was accompanied by a significant increase in angulation of the proximal end of the endograft at 1 year compared to NM patients (p = 0.01). By ANOVA, there was a statistically significant correlation between lateral endograft movement and longitudinal migration (r² = 0.26, p < 0.0001), proximal endograft angulation change (r² = 0.11, p = 0.01), and preoperative aneurysm size (r² = 0.16, p = 0.002). There was no significant correlation between lateral movement and change in aneurysm size at 1 year (p = 0.8).

Clinical Outcome

During a mean follow-up of 54 ± 26 months (range 12–102), a type I endoleak was found in 16 (27%) of 60 patients at some point during the observation period (Table 3). Twenty-one (35%) patients required a secondary intervention. There was no significant difference in the incidence of type I endoleak or secondary intervention between patients with LM and NM at 1 year. However, patients with LM were significantly more likely to develop an adverse clinical event during long-term clinical follow-up than NM patients. Eight (50%) LM patients developed a type I endoleak at some time compared to 8 (18%) NM patients (p = 0.02). Secondary procedures were performed in 12 (75%) LM patients versus 9 (20%) NM patients (p = 0.0002). One patient with LM experienced aneurysm rupture and 2 LM patients required conversion to open repair. All patients survived, and there were no aneurysm-related deaths. There were no ruptures or conversions in NM patients.

Lateral Movement Versus Longitudinal Migration

Of the 60 patients in this study, 8 (13%) were found to have longitudinal migration of the proximal endograft ≥ 10 mm at 1 year (Table 4). None of these 8 patients with longitudinal migration had a type I endoleak or required a secondary intervention at 1 year.
However, over the long term, 5 of these 8 patients developed a type I endoleak or required a secondary intervention, or both. These results were comparable to those seen in the LM cohort. However, the patient who experienced rupture and 1 of the 2 patients requiring conversion to open repair were not in the longitudinal migration group.

**DISCUSSION**

Endovascular AAA repair has gained increasing popularity over the traditional open approach in recent years, with over 50% of patients requiring AAA intervention undergoing EVAR in some institutions.\(^{10–12}\) However, ongoing concern about the long-term durability of EVAR necessitates frequent postoperative ultrasound or CT surveillance for positional endograft changes.\(^{13–15}\)

Biomechanical analyses of post-EVAR hemodynamics confirm the presence of strong forces on the endograft that can contribute to longitudinal migration.\(^{16}\) Not surprisingly, a number of studies have implicated inadequate proximal fixation as a cause of subsequent migration.\(^{17,18}\) However, some endografts exhibit significant migration despite adequate proximal fixation,\(^{19}\) and others remain stable in the absence of good proximal fixation.\(^7\) In line with these findings, our study found no significant difference in postoperative proximal fixation length between patients with lateral endograft movement and those without.

Recently, distal (iliac) fixation has been implicated as an important factor in determining risk for migration.\(^7,20\) Although we found a greater device–to–hypogastric artery distance in LM patients, there was no difference in iliac fixation length between the groups. Proximal and distal fixation characteristics are likely to play roles in endograft stability; however, they do not tell the whole story.

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**TABLE 2**

Changes in Aneurysm Size and Endograft Position at 1 Year

<table>
<thead>
<tr>
<th></th>
<th>Lateral Movement (≥5 mm)</th>
<th>No Lateral Movement (≤5 mm)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral endograft movement, mm</td>
<td>9±4</td>
<td>2±1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Longitudinal migration, mm</td>
<td>8±6</td>
<td>4±3</td>
<td>0.003</td>
</tr>
<tr>
<td>Longitudinal migration ≥10 mm</td>
<td>5 (31%)</td>
<td>3 (7%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Change in angulation of proximal graft, mm</td>
<td>4±3</td>
<td>2±2</td>
<td>0.01</td>
</tr>
<tr>
<td>Aneurysm size, cm</td>
<td>6.2±1.6</td>
<td>5.2±1.1</td>
<td>0.005</td>
</tr>
<tr>
<td>Change in aneurysm size, mm</td>
<td>−3±7</td>
<td>−4±7</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Continuous data presented as means ± standard deviations; categorical data are given as counts (percentages).

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**TABLE 3**

Clinical Outcomes in Patients With ≥5-mm Lateral Endograft Movement at 1 Year

<table>
<thead>
<tr>
<th></th>
<th>At 1 Year (n=16)</th>
<th>No Lateral Movement (n=44)</th>
<th>p</th>
<th>At Last Follow-up (n=16)</th>
<th>No Lateral Movement (n=44)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I endoleak</td>
<td>2 (13%)</td>
<td>2 (5%)</td>
<td>0.29</td>
<td>8 (50%)</td>
<td>8 (18%)</td>
<td>0.02</td>
</tr>
<tr>
<td>Secondary interventions</td>
<td>5 (31%)</td>
<td>5 (11%)</td>
<td>0.11</td>
<td>12 (75%)</td>
<td>9 (20%)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Conversion to open repair</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2 (13%)</td>
<td>0 (0%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Aneurysm rupture</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1 (6%)</td>
<td>0 (0%)</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Data are given as counts (percentages).

* Mean 4.5±2.2 years.
story. Until now, little attention has been paid to the mid-portion of the aortic endograft, which lies unsupported within the aneurysm sac. For this reason, we proposed that lateral movement of the mid-portion of the endograft over time may contribute to migration and thus serve as an indicator of long-term endograft instability.

We sought to reliably quantitate lateral movement in a manner that could be easily and rapidly reproduced in the clinical setting. Accordingly, measurement of lateral movement was performed on serial cross-sectional CT studies using standard software available in most hospital settings. The rostro-caudal midpoint of the abdominal aorta (between the inferior SMA orifice and the aortic bifurcation in our study) was chosen because we believed that maximal lateral endograft movement in subsequent studies could be best detected at this level, which was usually the point of maximal AAA diameter. Furthermore, the SMA orifice and the aortic bifurcation are easily recognizable landmarks that may allow reliable reproduction of measurements from one clinician to the next.

Once the appropriate CT slice was selected in the postprocedure study, an anatomically equivalent slice was identified on the 1-year CT using the vertebral body as a reference point. The vertebral body was selected because, with the exception of trauma or significant degenerative disease, it is a stable structure that undergoes no positional variation with respiration. For the same reason, the anterior-most portion of the vertebral body was used as an anatomical reference for the measurement of lateral positional changes over time.

Of all pre- and postoperative aneurysm characteristics that we recorded, only aneurysm size and device-to-hypogastric artery distance were found to differ between patients with lateral movement and no movement. Interestingly, proximal fixation was similar in the 2 groups, suggesting that it played no significant role in preventing lateral movement in this patient cohort. Furthermore, there was no difference in the distribution of suprarenal and infrarenal devices (suprarenal stent-grafts having longer proximal fixation). The shorter device-to-hypogastric artery distance in patients with lateral movement suggests that instability of the endograft distally may have contributed to this movement, but iliac fixation length was equal in both groups. The correlation between aneurysm size and lateral movement suggests that larger aneurysms may be predisposed to lateral movement, perhaps because the mid-portion of the endograft has more space in which to move.

Type I endoleak was detected in 27% of all patients during long-term follow-up. Patients requiring secondary intervention represented 35% of the total cohort. These rates are higher than those reported in a number of other studies with larger patient populations, which may be due to two factors. First, the total follow-up time in our study was quite long, with outcome data available for an

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>Clinical Outcomes in Patients With Lateral Endograft Movement Compared to Patients With Endograft Migration ≥10 mm at 1 Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 1 Year</td>
<td>At Last Follow-up*</td>
</tr>
<tr>
<td>Lateral Movement (n=16)</td>
<td>Longitudinal Migration ≥10 mm (n=8)</td>
</tr>
<tr>
<td>Type I endoleak</td>
<td>2 (13%)</td>
</tr>
<tr>
<td>Secondary interventions</td>
<td>5 (31%)</td>
</tr>
<tr>
<td>Conversion to open repair</td>
<td>—</td>
</tr>
<tr>
<td>Aneurysm rupture</td>
<td>—</td>
</tr>
</tbody>
</table>

Data are given as counts (percentages).
* Mean 4.5±2.2 years.
average of 4.5 years. Second, criteria for inclusion in this study required that patients have serial digital imaging sets available for analysis. The 60 patients represent only 10% of the total number of EVAR patients at our institution who were followed in our prospective database during this timeframe. The very long follow-up and the requirement for multiple serial imaging studies likely selected a high-risk population of EVAR patients: those with complex anatomy at risk for late endograft failure, which thus required especially close follow-up. This is in line with other studies that suggest that patients with favorable anatomy may not require follow-up CT scans as frequently.\textsuperscript{21,24} We routinely follow these “low-risk” patients with duplex ultrasound rather than CT. Although the presence of lateral movement $\geq 5$ mm at 1 year corresponded to a relatively high rate of adverse clinical events, it was not perfect at predicting long-term outcome. While the LM group included half of the type I endoleaks and the majority of patients requiring secondary intervention, 18% of patients with no lateral movement experienced a type I endoleak during long-term follow-up and 20% required a secondary intervention. However, the commonly accepted standard of caudal longitudinal migration $\geq 10$ mm\textsuperscript{25,26} was no better at predicting adverse long-term outcome in our patient group; it correctly identified only a quarter of the type I endoleak and patients and those requiring secondary intervention. If we used a more conservative cutoff of $\geq 5$ mm (n = 24), the result was similar, with 38% of patients experiencing endoleak and 50% requiring second intervention in long-term follow-up; again, 7 patients with endoleak and 9 patients requiring secondary intervention were overlooked by this categorization. Thus, despite missing some patients with subsequent adverse events, lateral movement was at least as sensitive and specific at identifying such high-risk patients as was longitudinal migration, if not better. Further studies with larger patient populations will help to confirm these results. The fact that endoleak can occur in the absence of lateral movement supports the premise that there are multifactorial determinants of endograft stability.\textsuperscript{21,27–29} Nonetheless, our results strongly suggest that lateral movement may be an important and fundamental contributor to stent-graft migration.\textsuperscript{342}

Limitations

The patients included in this study were only 10% of our total endograft patient population and represent only a high-risk subgroup. The relatively small study population limits the power of our results and may not be representative of all EVAR patients.

Conclusion

This study demonstrates that lateral movement of the endograft within the aneurysm sac is a predictor of late adverse events following EVAR. Our results suggest that stabilization of the mid-portion of the endograft to prevent lateral movement may help prevent endograft displacement and late adverse events. This observation requires further study.

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REFERENCES


