Symptomatic adjacent segment disease (ASD) after anterior cervical fusion (ACF) is reported in 25% of patients at 10 years postoperatively. Debate continues as to whether this degeneration is due to the natural history of the disk or the changed biomechanics after ACF. This study explored whether congenital stenosis predisposes patients to an increased incidence of ASD after ACF.

A retrospective review of 635 patients with myelopathy or radiculopathy was performed; 364 patients had complete records for review. Patients underwent 1- to 5-level ACF (94 one-level, 145 two-level, 79 three-level, 45 four-level, and 1 five-level). Radiographs were evaluated for bony congenital stenosis using validated parameters, and ASD was measured according to Hilibrand’s criteria and correlated with symptomatic ASD. Congenital stenosis was found in 21.7% of patients and radiographic ASD in 33.5%, with a significant association between these parameters. However, symptomatic ASD occurred in 11.8% of patients; no association between congenital stenosis and symptomatic ASD or myelopathy and ASD was found. Clinical results demonstrated excellent or good Robinson scores in 86.2% of patients and Odom scores in 87% of patients.

Despite mostly excellent to good outcomes, symptomatic ASD is common after ACF. Although congenital stenosis appears to increase the incidence of radiographic ASD, it does not appear to predict symptomatic ASD.

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With the advent of cervical disk arthroplasty, renewed attention has been given to adjacent segment disease (ASD) after anterior cervical fusion (ACF) surgery. It has been suggested that ACF procedures may increase the rate of ASD secondary to a change in the normal cervical biomechanics. The fused segments create hypermobility at the adjacent segments and may lead to increased biomechanical stress on the adjacent level. A similar phenomenon has been observed in the lumbar spine.

Adjacent segment disease is common, occurring in up to 25% of patients at 10 years after the index procedure. However, no agreement exists as to whether this degeneration at adjacent levels is secondary to the ACF, the result of the natural history of the adjacent disk, the result of inadvertent iatrogenic trauma to the disk intraoperatively, or the result of some combination thereof. Numerous articles have attempted to further define the etiology of ASD.

Congenital stenosis of the cervical spine has also been shown to be associated with the development of degenerative disk disease. The independent association of ACF and congenital stenosis with degenerative changes in the cervical spine suggests that an additive or linked association between congenital stenosis and ASD may exist.

**Materials and Methods**

A retrospective cohort study of 635 patients was performed. All patients underwent 1 of the following procedures: anterior cervical discectomy and fusion, anterior cervical corpectomy and fusion, or anterior cervical hemi-corpectomy or partial corpectomy and fusion. For this study, radiographic adjacent segment degeneration and clinical disease were grouped together.

**Patient Selection**

Patients were collected from 2 surgeons’ (J.D.K.) experiences at 2 large academic medical centers. All patients underwent ACF between 1973 and 2003. Average follow-up was 36.7 months. Exclusion criteria included previous posterior cervical fusion; radiographic evidence of ossification of the posterior longitudinal ligament; and a diagnosis of ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, muscular dystrophy, or spinal tumor.

**Chart Review**

Medical records were reviewed for all 635 patients to identify those exhibiting clinical ASD. Clinical outcome scores were assigned using Robinson and Odom scores based on follow-up documentation. Patients had a median follow-up time of 36.2 months (range, 1-263 months). Radiology reports were also reviewed, when available and applicable, to identify postoperative ASD.

**Radiographic Review**

Radiographs were available for 364 patients. Pre- and postoperative radiographs were compared to assess the development of ASD, which was defined as a change in pre- to postoperative Hilibrand score (Table 1) as assigned by the reviewer (J.B.). Patients did not have radiographic ASD if degenerative changes according to the Hilibrand score were not observed between the pre- to postoperative radiographs. The presence of congenital stenosis was defined as a Pavlov ratio less than 0.80. The Pavlov ratio was used to determine stenosis in an attempt to standardize the measurements because the relative magnification of the lateral radiograph could not be determined precisely on the older radiographs in this patient cohort. This method has been previously reported in the same patient cohort and shown to have high interobserver reliability (r=0.96; P<.001) in this patient population. In the current analysis, all radiographs were reviewed by 1 of 2 surgeon investigators (J.B., J.H.), and the reliability of measurement was found to be excellent (κ=0.892; P<.001).

**Results**

A total of 635 patients were reviewed both radiographically and clinically for

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**Table 1**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Disease</th>
<th>Plain Radiographs</th>
<th>MRI</th>
<th>CT, Myelography, or Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>None</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>II</td>
<td>Mild</td>
<td>Narrowing of disk space, no posterior osteophytes</td>
<td>Signal change in intervertebral disk</td>
<td>Normal</td>
</tr>
<tr>
<td>III</td>
<td>Moderate</td>
<td>&lt;50% of normal disk height, posterior osteophytes</td>
<td>Herniated nucleus pulposus without neural compression</td>
<td>Herniated nucleus pulposus; no nerve root cutoff or spinal cord compression</td>
</tr>
<tr>
<td>IV</td>
<td>Severe</td>
<td>Same as grade III</td>
<td>Spinal cord compression with or without nerve root compression</td>
<td>Nerve root cutoff with or without spinal cord compression</td>
</tr>
</tbody>
</table>

*Abbreviation: CT, computed tomography; MRI, magnetic resonance imaging.*
ASD after undergoing ACF procedures between 1978 and 2003. Of these, 364 patients (42.4% men, 57.5% women) had complete follow-up data available. Mean follow-up was 36.2 months (range, 1-263 months). Mean age patient age was 51.6 years (range, 18-86 years). The majority of patients underwent either a 1- or 2-level fusion (n=94 and 145, respectively), with 79 undergoing 3-level fusion, 45 undergoing 4-level fusion, and 1 undergoing 5-level fusion.

The overall incidence of radiographic ASD was 33.5%, whereas the incidence of congenital stenosis was 21.7%. A statistically significant association was observed between congenital stenosis and radiographic degeneration as scored by the Hilibrand criteria (P= .011) (Table 2). However, this did not correlate with clinical symptoms, and no association was found between symptomatic ASD (11.8%) and congenital stenosis (P=.239) (Table 3).

Further analysis showed no significant relationship between the preoperative clinical diagnosis and ASD. More specifically, myelopathy did not predict ASD (P=.293) (Table 4). Similarly, average Pavlov ratios were obtained for each patient, and a 2-tailed independent t test for equality of means was performed to assess for any association between this ratio and the development of ASD. No statistically significant association was found (P=.601).

The temporal nature of symptomatic ASD was also evaluated. Patients with congenital stenosis did not appear to develop symptoms attributable to ASD sooner than patients with nonstenotic canals (P=.862). Despite the high rate of ASD, overall outcomes for patients were positive, with 86.2% of patients having good to excellent Robinson scores and 87% of patients having good to excellent Odom scores.

**Discussion**

Since Hilibrand et al. described the new onset of myelopathic and radiculopathic symptoms adjacent to prior anterior fusions, ASD and its etiology has become a topic of considerable interest. In their study, Hilibrand et al. found the annual incidence of symptomatic ASD to be 2.9% of all ACFs. Other studies have found rates of symptomatic ASD ranging from 2% to 25%. Similarly, the incidence of asymptomatic ASD appears to be significantly higher, ranging from 16% to 73.2%. Similarly, a high incidence of ASD has been noted following corpectomy and fusion. Kulkarni et al. reported that 38.7% of patients show either radiographic or clinical evidence of ASD after corpectomy and fusion.

Identification of the risk factors for ASD development should enable surgeons to identify patients at the greatest risk for ASD and inform their monitoring and follow-up decisions. The length of the fusion, whether C5-C6 or C6-C7 is an adjacent segment to the ASD, and improper sagittal alignment have all been identified as risk factors for the development of ASD. Finn et al. found that where 2 noncontiguous segments require fusion, the risk of ASD is lower with 2 smaller fusions compared with a larger spanning fusion. Komura et al. reported that fusions that leave either C5-C6 or C6-C7 as an adjacent segment, as opposed to incorporating those segments into the fusion, were more likely to develop ASD. The incidence of ASD decreases with proper lordotic sagittal alignment following ACF. Neither posterior fusion nor cervical disk arthroplasty significantly decrease the risk of ASD.

Congenital stenosis has previously been shown to be a risk factor for degenerative disk disease as measured in magnetic resonance imaging studies. In the current study, it was hypothesized that congenital narrowing of the cervical canal would lead to an increased rate of ASD following ACF. Interestingly, it appears that congenital narrowing may be associated with a greater degree of radiographic degeneration at the adjacent level.
Although the current study is the largest to date on congenital stenosis of the cervical spine, it has some limitations. It is a retrospective review in which the preponderance of the radiographic records were limited and, in some cases, incomplete. The majority of these records were from a time before digital imaging and included poor-quality, unscaled radiographs, magnetic resonance images, or computed tomography scans. Therefore, in an effort to standardize the available imaging studies, radiographers were used to determine congenital narrowing via the Pavlov ratio. Although this method is not the most precise technique for determining the canal size, it allows for the most accurate measurement in radiographs in which the relative magnification is uncertain, as was the case in this series. It is possible that more precise, digitally obtained measurements might have altered the final numbers in some groups. However, it is unlikely that this would have altered the study findings. This allows room for another large-scale study using digital imaging to further explore this question. Nonetheless, a standardized, previously published, and validated technique for radiographic assessment was used in this study, and the findings are consistent with previously published material, as well as clinical experience on this topic. For this reason, the current authors believe the findings presented in this study are clinically important and help to guide understanding of ASD in the congenitally narrow cervical spine.

CONCLUSION

Congenital stenosis appears in 21.7% of patients undergoing ACF. Despite a predominance of excellent to good surgical outcomes, symptomatic ASD is common, occurring in 11.8% of patients. Although radiographic ASD appears to correlate with congenital stenosis, clinically symptomatic ASD does not. Adjacent segment disease may represent the natural history of the degenerating disk rather than the end product of underlying biomechanics of the congenitally stenotic cervical canal or the change in forces created by surgical arthrodesis.

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