THE EFFECTS OF OVER-DISTRACTION ON ADJACENT SEGMENT DISEASE AND CAGE SUBSIDENCE IN ANTERIOR CERVICAL DISCECTOMY AND FUSION

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Abstract

Over-distraction has been identified as a risk factor for cage subsidence and postoperative neck pain following anterior cervical discectomy and fusion (ACDF). Biomechanical studies have also shown increased intradiscal pressure at adjacent segments after ACDF. This study aims to investigate whether over-distraction of the index disc affects adjacent segment pathology. A retrospective review was conducted on 145 patients who underwent primary ACDF for cervical degenerative conditions between January 2016 and December 2023. Patients were categorized into two groups: (1) Over-distraction group (postoperative–preoperative index disc height difference ≥ 2 mm), and (2) No-distraction group (postoperative–preoperative index disc height difference < 2 mm). Outcome measures included radiographic parameters, Japanese Orthopaedic Association (JOA) score, and the incidences of cage subsidence, as well as radiological and clinical adjacent segment pathologies (RASP and CASP), which were assessed preoperatively, postoperatively, and at final follow-up.

Both groups were similar in terms of age, length of follow-up, JOA score, CASP incidence, and radiographic parameters. However, the Over-distraction group (83 patients, 115 levels) had a lower preoperative index disc height (4.5 mm vs. 5.2 mm, $p < 0.001$) and a greater postoperative index disc height (7.7 mm vs. 6.6 mm, $p < 0.001$) compared to the No-distraction group (62 patients, 90 levels). The Over-distraction group also exhibited significantly higher rates of cage subsidence (47% vs. 31%, $p = 0.04$) and RASP (any progression: 48% vs. 15%, $p < 0.001$; progression ≥ 2 grades: 25% vs. 7%, $p = 0.001$). Multivariate analysis revealed that both over-distraction and multilevel fusion were independent risk factors for RASP. Despite these findings, no differences in clinical outcomes were observed between the two groups. The study concludes that over-distraction of the index level by ≥ 2 mm should be avoided, as it significantly increases the risk of RASP and cage subsidence.

Keywords: Discectomy and fusion (ACDF), polyetheretherketone (PEEK), adjacent segment pathology (ASP), radiological adjacent segment pathology (RASP).

Introduction

Since its introduction by Smith and Robinson, anterior cervical discectomy and fusion (ACDF) has been established as a safe and effective treatment for cervical degenerative conditions. The procedure involves the complete removal of disc material and protruding osteophytes, followed by the placement of autologous bone grafts, allografts, interbody spacers, or combinations thereof. A variety of materials are used as interbody spacers, with polyetheretherketone (PEEK) cages being widely favored due to their excellent biocompatibility and radiolucency, which allows for easier assessment of fusion. Porous tantalum trabecular metal (TM) cages are also notable for their high porosity and biomechanical properties, which closely mimic bone. Other materials, such as carbon fiber composite cages, offer an elastic modulus similar to bone, reducing stress shielding and promoting bone fusion, as described by Wolff's law. However, titanium cages have been

associated with subsidence, leading to disc height collapse and kyphotic deformity in previous studies.

One major concern following ACDF is adjacent segment pathology (ASP), which occurs at an annual incidence of 2.9%. ASP can be classified into clinical adjacent segment pathology (CASP) and radiological adjacent segment pathology (RASP), depending on whether it presents with clinical symptoms. CASP typically manifests as radiculopathy, myelopathy, or axial neck pain. Various surgical techniques have been suggested to reduce ASP risk, including motion-preserving total disc arthroplasty, limiting damage to adjacent discs and the anterior longitudinal ligament, and restoring normal cervical sagittal alignment.

Cage subsidence is another complication that can negatively affect surgical outcomes. Subsidence leads to decreased foraminal height, local kyphosis, and disrupted cervical sagittal alignment as the cage sinks into the vertebral body. Although anterior plating is sometimes used to enhance stability and fusion rates, it has been associated with complications such as postoperative dysphagia, ASP due to anterior longitudinal ligament damage, and reduced micromotion at the bone-graft interface due to rigid fixation.

To restore disc height, surgeons often select larger-sized grafts or cages during ACDF. However, larger cages (greater than 5.5 mm) have been linked to a higher risk of subsidence. Additionally, studies have shown that patients with cage subsidence had significantly higher distraction ratios than those without. The goal of our research is to explore how over-distraction impacts radiographic parameters, cage subsidence, adjacent segment pathology, and clinical outcomes in patients undergoing ACDF surgery.

Materials and Methods

This retrospective study reviewed a consecutive series of patients who presented with myelopathy or radiculopathy caused by cervical degenerative pathologies and underwent primary anterior cervical discectomy and fusion (ACDF) between January 2016 and December 2023 at our institute.

The inclusion criteria were: (1) Patients who underwent primary ACDF at 1 or 2 levels, and (2) Patients with a follow-up period of at least 24 months. Exclusion criteria included: (1) Surgery for non-degenerative conditions such as traumatic injury, malignant tumors, or infection; (2) ACDF performed at more than 3 levels; (3) Patients who received cervical disc prostheses; (4) Revisional cervical spine surgeries; (5) Patients who underwent anterior plate augmentation, and (6) Follow-up period of less than 24 months.

Results

Comparisons of Radiographic Parameters Between the Two Groups

All measurements were taken by two spine fellows, and the interrater agreement was excellent, with an ICC of 0.907 (95% CI 0.822–0.950). The Over-distraction group had a significantly smaller preoperative index disc height (4.5 mm vs. 5.2 mm, $p < 0.001$), but a greater postoperative index disc height (7.7 mm vs. 6.6 mm, $p < 0.001$) and local Cobb angle (9.8° vs. 7.7°, $p = 0.04$) compared to the No-distraction group. However, by the final follow-up, the index disc height (4.8 mm vs. 4.5 mm, $p = 0.35$) and local Cobb angle (5.2° vs. 5.0°, $p = 0.86$) were similar between the two groups. All other radiographic parameters, except for postoperative cSVA (25.8 mm vs. 19.8 mm, $p = 0.03$), were comparable between the groups at the preoperative, postoperative, and final follow-up time points.

Risk Factors for RASP

In the univariate analysis, significant risk factors included over-distraction, multilevel fusion, TM cage implantation, smaller preoperative neck tilt, longer follow-up duration, and a smaller preoperative local Cobb angle. Multivariate analysis identified over-distraction (Odds Ratio [OR] = 7.52; 95% Confidence Interval [CI]: 2.82–20.04) and multilevel fusion (OR = 2.52; 95% CI: 1.12–5.68) as independent risk factors for RASP.

Discussion

Porous tantalum cages and polyetheretherketone (PEEK) cages are commonly used in ACDF. Porous tantalum cages have biomechanical properties similar to cancellous bone, allowing for efficient load transfer and minimizing the stress-shielding effect. PEEK, on the other hand, is chemically inert and does not promote protein absorption or enhance cell adhesion and bone contact when compared to titanium. Both TM cages and PEEK cages have demonstrated high fusion rates in both the cervical and lumbar spine. However, previous studies have shown that TM cages have a higher rate of subsidence compared to PEEK cages. In this study, we included patients who underwent ACDF with either TM or PEEK cages, and the overall fusion rate of 88% was consistent with prior reports.

Distraction of the intervertebral disc space helps improve visibility during disc material removal and posterior osteophyte resection. However, excessive distraction force can cause damage to the facet joints at the index level. Kirzner et al. reported that over-distraction of the facet joint by 3 mm or more is associated with poorer functional outcomes and higher pain scores in patients with traumatic cervical injuries treated with ACDF. Additionally, excessive distraction may increase the pressure on adjacent discs and stress on surrounding structures. Yuan et al. conducted a finite element study investigating the effect of disc arthroplasty height on cervical biomechanics, showing that prostheses with a height increase of 2 mm or more significantly raised intradiscal pressure, facet joint forces, and bone-implant interface stress compared to prostheses with less than 2 mm of height increase.

Interestingly, regardless of the degree of distraction, our results showed that the index disc heights in both groups collapsed to a similar extent at the final follow-up. The physiological tension of surrounding muscles and ligaments may play a role in determining the final disc height after ACDF with grafts or cages. Aryan et al. suggested relaxing the distraction force after discectomy, demonstrating that the same level of distraction could be achieved with 20N less force after the removal of intervertebral discs. Given that excessive distraction force may interfere with physiological tension and influence the selection of graft or cage size, we recommend releasing the distraction force during sizing trials to avoid selecting oversized grafts or cages, as supported by the findings of this study.

Conclusions

In conclusion, over-distraction of the index level by 2 mm or more significantly increases the risk of RASP, CASP, and cage subsidence. Based on these findings, we recommend releasing the distraction force during graft/cage size selection in ACDF to prevent over-distraction of the disc height, thereby reducing the incidence of RASP, CASP, and cage subsidence.

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