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Clinical Study

Comparison of adjacent segment disease after minimally invasive or open transforaminal lumbar interbody fusion

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ABSTRACT

Adjacent segment disease (ASD) is a potential long-term risk after lumbar fusion. Its incidence has been evaluated in anterior and posterior lumbar interbody fusions, but few studies have focused on transforaminal lumbar interbody fusion (TLIF). Relative risk of ASD with open or minimally invasive (MI) TLIF is poorly understood. To report our experience with risk for ASD in patients receiving TLIF and test its association with surgical approach, we performed a retrospective cohort study based on medical record review at a single institution. Eligible patients were ⩾18 years old at operation, underwent single-level TLIF during the period 2007–2008, and had at least 6 months postoperative follow-up. Patients were categorized by surgical approach (open *versus* MI). Primary outcome of interest was development of symptomatic ASD, defined by (1) new back and/or leg pain, (2) imaging findings adjacent to original surgical level, and (3) decision to treat. A total of 68 patients (16 open, 52 MI) were included in the analysis. Groups had similar baseline characteristics, except the open group tended to be older ($p = 0.04$). Seven (10%) patients developed ASD. Mean patient age was 62 years and three were male. Three underwent open and four underwent MI TLIF. Risk of ASD did not differ significantly by surgical approach. The MI group showed a trend toward decreased risk of ASD compared to the open group, although it was not statistically significant. This suggests MI TLIF may be associated with decreased long-term morbidity compared to the open approach. Large prospective studies are needed to confirm these findings.

1. Introduction

Adjacent segment disease (ASD) – symptomatic degenerative changes at levels adjacent to those that underwent prior surgical intervention – can occur after lumbar arthrodesis [1–5]. Pathologic processes observed at adjacent segments include disc degeneration, listhesis, instability, herniated nucleus pulposus, stenosis, and compression fractures [6–8]. ASD is a particularly concerning phenomenon because it can lead to worsened pain and functional outcomes following surgical intervention of the lumbar spine and may require surgical re-intervention. While the risk of asymptomatic degenerative changes following lumbar arthrodesis has been reported to be as high as 57% [9], the reported risk of symptomatic ASD is between 1.9% and 30.3% [10–14].

While ASD has been studied in anterior lumbar interbody fusion (ALIF) [7,15] and posterior lumbar interbody fusion (PLIF) [2,16,17], it has not been as well-characterized in transforaminal lumbar interbody fusion (TLIF). While TLIF offers distinct advantages over PLIF, it still requires a similar degree of paraspinal muscle stripping and substantial excision of bone and ligamentous structures, which may compromise lumbar stability and lead to ASD [18–21]. Minimally invasive (MI) TLIF involves less adjacent tissue destruction, reducing the morbidity associated with open TLIF. Several studies have shown similar outcomes in pain and function while reducing the risk of perioperative complications seen in open TLIF [22–25]. However, comparative data regarding long-term complications such as ASD in patients undergoing open or MI TLIF are scarce, necessitating further investigation.

In this study, we report the overall incidence of ASD among patients undergoing TLIF and compare its occurrence in open and MI TLIF populations. We hypothesized that ASD occurrence would be lower in the MI TLIF group than in the open group, given the enhanced preservation of the inherent stabilizing elements of the spine.

2. Methods

Approval was obtained from the University of Michigan Institutional Review Board prior to performing this study.

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2.1. Study design

We performed a retrospective cohort study [26]. For the study's main comparison, patients were categorized according to whether they underwent open or MI TLIF, based on operative notes in the electronic medical record.

2.2. Patient population

Patients who underwent open or MI TLIF between 2007 and 2008 at the University of Michigan were retrospectively identified through the use of electronic medical records. Eligible patients were $\geqslant$18 years of age, underwent a single-level TLIF, and had at least 6 months of clinical and radiographic follow-up postoperatively. The MI TLIF technique employed in these patients has been described in the literature [27].

2.3. Data collection and outcomes assessment

Data pertaining to patient demographics (including age, sex, and body mass index [BMI]) and medical history (including diabetes mellitus, hypertension, and malignancy) were collected from electronic health records.

The outcome of interest in this study was the development of ASD, defined by (1) new back or leg pain, (2) confirmatory imaging findings adjacent to the original surgical level, and (3) decision to treat the new symptoms. Both lumbar radiographs and MRI were utilized for radiographic follow-up.

2.4. Statistical analysis

Descriptive data were analyzed via univariate statistics. Continuous variables were described using means and standard deviations (SD). Categorical variables were described with frequencies. Continuous variables between open and MI groups were compared via two-sample Student's *t*-test, and categorical variables via chi-squared or Fisher's exact test. Because we recorded time from TLIF operation until development of ASD, we performed time-to-event analysis and calculated a hazard ratio (HR). Kaplan–Meier curves were used to describe time to ASD development; ASD occurrence was compared in patients undergoing open *versus* MI TLIF using the log-rank test. Given that (1) imaging and clinical diagnosis may have lagged behind pathological development of ASD, (2) some uncertainty exists concerning the exact time of ASD development, and (3) data were collected retrospectively via electronic medical records, we employed parametric regressions that could accommodate interval censoring instead of a Cox proportional hazards model. For those patients who developed ASD, the lower bound was defined as the date when the patient was either last known to be ASD-free or else the first possible mention of symptoms consistent with ASD. The upper bound was defined as the date at which we had sufficient clinical and radiographic evidence to formally make a diagnosis of ASD (mean, 3 months; SD, 2 months). To determine the best-fitting parametric model, we compared likelihood ratios and examined probability plots. This analysis demonstrated that the Weibull hazard function provided the best fit. Nevertheless, we still performed sensitivity analyses using various types of regressions including a Cox proportional hazards regression and a variety of parametric hazard functions, including exponential and log-normal distributions. We tested the proportional hazards assumptions of a Cox model via inclusion of an interaction term between the main covariate and time, as well as via analysis of Schoenfeld and martingale residuals. The small number of events limited the utility of adjusting for potential confounders via multivariable regressions, but it was attempted to generate an adjusted HR.

A p value <0.05 was considered statistically significant. All statistical analyses were performed using SAS software, version 9.3 (SAS Institute, Cary, NC, USA).

3. Results

We identified 69 patients who underwent single-level TLIF between 2007 and 2008. One patient was excluded due to less than 6 months of postoperative follow-up, resulting in a sample size of 68. Baseline characteristics were similar between the open (n = 16) and MI (n = 52) groups (Table 1), except the open group was older (p = 0.04). Overall mean age was 50 years (SD, 14 years). Overall mean radiographic follow-up time was 33 months (SD, 20 months) and did not differ between groups (p = 0.95).

Selected characteristics of the seven patients who developed ASD are summarized in Table 2 (Fig. 1). Mean age of ASD patients was 62 years (SD, 10 years). Of these patients, three were male. Six had fusion at L4–L5, and one had fusion at L3–L4. Three underwent open TLIF, and four underwent MI TLIF. Four had an ASD diagnosis of a herniated disc, two had stenosis, and one had disc degeneration with retrolisthesis. Five developed ASD above their original level of fusion. Mean time to ASD diagnosis from operative date was 48 months (SD, 18 months). Frequency of ASD occurrence was not significantly associated with a particular level (p = 0.14) (Table 3).

The risk of ASD was 7/68 (10%) overall, which did not differ significantly by surgical approach (MI: 4/52 [8%], open: 3/16 [19%]; p = 0.34; relative risk [RR] = 0.41; 95% confidence interval [CI] 0.10–1.6) (Fig. 2). Incidence rate was 0.04 cases of ASD per person-years overall; 0.03 for the MI group, and 0.07 for the open group (incidence rate ratio 0.03/0.07 = 0.39).

Figure 3A displays a Kaplan–Meier curve of time to ASD development in the overall cohort. Figure 3B presents a Kaplan–Meier curve stratified by surgical approach; the two survival curves did not differ significantly (p = 0.28). On average, the MI group took 33% longer to develop ASD (acceleration factor = 1.33; 95% CI 0.81–2.2). The unadjusted HR was 0.40 (95% CI 0.08–1.9); adjusted for age, HR was 0.96 (95% CI 0.16–5.9). Results were similar when we employed right-censored instead of interval-censored analysis, as well as when we employed a Cox proportional hazards model and other parametric hazard distributions.

4. Discussion

ASD has been documented following lumbar arthrodesis [2,4], although its etiology [21,28,29] and risk factors [18] have not yet been fully elucidated. Although the natural history of ASD remains unclear, several post-arthrodesis mechanisms of its pathogenesis have been described. Fusion has been shown to cause biomechanical changes (for example, altered sagittal alignment) at adjacent levels, leading to increased range of motion and intradiscal pressure [28–32]. Presumably, these factors tend to increase facet loads and stress on the disc, thereby hastening degenerative changes. Moreover, particular techniques of lumbar arthrodesis (such as PLIF *versus* ALIF) may compromise lumbar stability via stripping of paraspinal muscles and excision of bone and ligamentous structures [18–21]. Strategies to reduce alteration of the biomechanical profile at adjacent segments include total disc arthroplasty [33] and dynamic fixation [34], but studies have been few and results inconclusive. While no consensus has been reached on demographic risk factors for ASD, studies have identified associations with increased age [10,35,36], smoking [37], pre-existing facet degeneration [38], and family history of disc degeneration [39].

Studies examining MI lumbar fusion and ASD are relatively scarce. Compromise of the posterior adjacent segment anatomy has been implicated in ASD [40], and MI techniques aim to reduce