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Impact of Increasing Age on Outcomes of Spinal Fusion in Adult Idiopathic Scoliosis

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Abstract

Objective—To investigate the role of advancing age on postoperative complications and revision surgery after fusion for scoliosis.

Methods—A retrospective, cohort study was performed using the Thomson Reuters MarketScan database, examining patients with adult scoliosis who underwent spinal fusion from 2000 to 2009. Primary outcomes included infection, hemorrhage and pulmonary embolism (PE) within 90 days of surgery, and refusion. The effect of increasing age was estimated using the odds ratio (OR) of complications in a multivariate logistic regression analysis, and a Cox proportional hazard model estimated the hazard ratio of refusion.

Results—A total of 8432 patients were included in this study. Overall, the average age was 53.3 years, with 26.90% males and 39% with a Charlson Comorbidity Score of 1. Most patients had commercial insurance (66.81%), with 26.03% and 7.16% covered by Medicare and Medicaid, respectively. Increasing age (per 5-year increment) was a significant predictor of hemorrhagic complication (OR, 1.06; confidence interval [CI], 1.01–1.11; $P=0.0196$), PE (OR, 1.09; CI, 1.03–1.16; $P=0.0031$), infection (OR, 1.04; CI, 1.01–1.07; $P=0.0053$), and refusion (hazard ratio, 1.07; CI, 1.02–1.13; $P=0.0103$).

Conclusions—In this study, age was associated with increased risk of hemorrhage, PE, infection, and refusion. With the aging population, the role of patient age on postoperative healing and outcomes deserves deeper investigation after repair of adult idiopathic scoliosis.

Keywords

Age; Outcomes; Scoliosis; Spinal fusion

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Introduction

Adult scoliosis is a highly prevalent and disabling condition that may develop de novo during adult life or progress from untreated adolescent scoliosis; it is associated with significant health care costs in the United States.¹⁻⁴ The overall prevalence has been reported to vary widely between 2% and 32%,⁵⁻⁹ and it is predicted to increase as the proportion of elderly individuals steadily increases.^{2,8-12} In a recent study by Schwab et al.,¹³ the prevalence of scoliosis was found to be 68% in healthy volunteers older than 60 years. Similarly, several longitudinal studies have reported an increased prevalence of scoliosis with age.^{1,9,14-18} As the population ages rapidly in the United States, the prevalence of scoliosis will increase, resulting in increased complex surgical intervention for symptomatic spinal disease.^{19,20} Complications after surgical correction of adult spinal deformity remains a major impediment to operative management. Despite satisfactory outcomes²¹⁻²³ and functional improvement,²⁴⁻²⁶ complications and reoperations are significant risks with surgical intervention.²² Relatively high rates of complications have been reported in previous studies evaluating adult patients with spinal deformity.^{12,27} Reoperation rates have ranged from 10% to 25%,^{17,28-30} with pseudarthrosis being one of the most common indications.³¹⁻³³ One major contribution to the high complication rates in the surgical correction of adult spinal deformity is advancing age, with several studies showing a correlation between increasing age and incidence of surgical complications.^{3,20,23,34-36} Most studies evaluating outcomes after repair of scoliosis have been single-institution studies,^{28,37-39} with few studies evaluating outcomes at a national level.⁴⁰ This study analyzes the role of advancing age on postoperative complications (hemorrhage, infection, pulmonary embolus) and revision surgery using a large, national retrospective database analysis.

Methods

Data Source

Data for the study were obtained using Thomson Reuter's MarketScan database, which contains information from Commercial Claims and Encounters, the Medicare Supplemental and Coordination of Benefits, and the Medicaid databases. The database captures patient-level data on clinical use (inpatient and outpatient), pharmaceutical claims, insurance enrollment, and costs, and links these data with detailed patient, provider, and facility information. The MarketScan database is a deidentified database that was deemed to be exempt from review by the institutional review board.

Study Sample

International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes were used to identify patients diagnosed with scoliosis (ICD-9-CM 737.30) who underwent spinal fusion (ICD-9 CM: 81.0-81.08) between 2000 and 2009. Based on this study design, all approaches for surgical correction were grouped and do not differentiate based on the type of surgery, which proves to be an unavoidable confounding factor based on use of an ICD-9 driven data source. All selected patients were required to have 90 days or more of enrollment. Observations with more than 1 spinal fusion

used the earliest recorded spinal fusion. Only patients aged 18 years and older at the time of the index hospitalization were included in the analysis. Patients were stratified into 3 groups based on age: group 1, 18–44 years; group 2, 45–64 years; group 3, 65+ years. Comorbidities were tallied and used to calculate a Charlson Comorbidity Index Score⁴¹ for each patient.

Postoperative Outcome Variables

Primary outcomes were postoperative complications within 90 days of surgery (hemorrhage or hematoma, infection, and pulmonary embolism [PE]) and the rate of refusion surgery was signified as a subsequent spinal fusion (repeated ICD-9-CM: 81.0-81.08) at a later date from the index spinal fusion surgery. The reasons for repeat fusion were varied and included situations such as adjacent segment disease, revision for poor placement, and implant failure. Complications within 90 days of surgery were assessed at any postoperative hospital admission using ICD-9 diagnosis. All cost estimates were based on patient-reported resource use.

Statistical Analysis

This retrospective cohort study reviewed the association of age with select outcomes among adult patients with scoliosis undergoing spinal fusion. A multivariate Cox proportional hazard model was selected to study refusion. Complications for infection and hemorrhagic and PE within 90 days of the operation were evaluated with multivariate logistic models. The rate of refusion was analyzed using the multivariate Cox proportional hazard regression models. Year of operation, a patient's Charlson Score, insurance type, gender, and age as a continuous variable were included in each model. Analyses report respective hazard ratios or odds ratios (ORs) with 95% confidence intervals (CIs). Statistical testing and associated P values are from a χ^2 distribution. All analyses were conducted with SAS version 9.3 (SAS Institute Inc., Cary, North Carolina, USA).

Results

Patient Cohort

A total of 8453 patients met the inclusion criteria for this study. Selected patients were 18 years and older with diagnosis of scoliosis and underwent spinal fusion as a treatment procedure. 22.39% of patients had a Charlson Comorbidity Score of 1, with 9.90% and 6.70% having a score of 2 and 3, respectively. Most of the patients (66.81%) were privately insured, with 26.03% and 7.16% covered by Medicare and Medicaid, respectively. Of the total number of patients, 25.66% were aged 18–44 years, 47.89% were 45–64 years, and 26.45% were 65+ years. Overall, the mean age \pm standard deviation was 53.3 \pm 18.04 years (group 1, 27.2 \pm 9.17 years; group 2, 56.5 \pm 5.34 years; group 3, 73.0 \pm 5.47 years). Among patients in group 1, 1.43% had a Charlson Score of 3 or more, compared with 6.24% and 12.65% in groups 2 and 3, respectively. Complete demographic characteristics of the cohorts are listed in Table 1.

Postoperative Outcome Variables

Overall, the most common complication within 90 days was infection, with a rate of 11.27% (group 1, 9.24%; group 2, 11.29%; group 3, 13.18%) (Table 2). The next most common complication was postoperative pneumonia, with a rate of 10.48% (group 1, 9.38%; group 2, 8.84%; group 3, 14.53%). The rate of hemorrhagic complication was 3.90% (group 1, 2.59%; group 2, 4.41%; group 3, 4.53%). The rate of refusion in this study was 2.87% (group 1, 2.03%; group 2, 3.52%; group 3, 2.51%, with the average \pm standard deviation number of years to refusion being 1.8 ± 1.78 years, 1.7 ± 1.7 years, and 1.9 ± 1.94 years, respectively). The overall mortality within 90 days was 0.32% (group 1, 0.14%; group 2, 0.27%; group 3, 0.58%).

Multivariate Analysis

Using a multivariate logistic regression analysis, our study showed that within 90 days of surgery, increasing age (per 5-year increment) was a significant predictor of hemorrhagic complication (OR, 1.06; CI, 1.01–1.11; $P = 0.0196$), PE (OR, 1.09; CI, 1.03–1.16; $P = 0.0031$) and infection (OR, 1.04; CI, 1.01–1.07; $P = 0.0053$) (Table 3). Analysis of refusion using the Cox proportional hazard model showed a 7% increased risk of having refusion surgery for every 5-year age increment (hazard ratio, 1.07; CI, 1.02–1.13; $P = 0.0103$). At 10 years after primary fusion, Kaplan-Meier survival estimates for refusion were 89.7%, 82.7%, and 87.9% for age groups 1, 2, and 3, respectively (Figure 1).

Discussion

Adult spinal deformity has a significant and measurable impact on health-related quality of life, affecting several domains, including pain, function, self-image, and mental health.^{8,9,15,24} There is increasing evidence suggesting the effectiveness of surgical treatment for adult spinal deformity; however, the relatively high reported rate of potential surgical complications has facilitated a trend toward nonoperative management, notwithstanding that longitudinal data on the effectiveness of conservative care are lacking.^{1,3,15,16}

Complications and reoperations after surgical repair for adult scoliosis remain an important concern. There remains a paucity of data evaluating and quantifying the impact of age on outcomes after primary fusion for adult scoliosis. Despite the increased risk of complications and mortality, elderly patients can benefit from significantly greater improvement in disability and reduced pain after scoliosis surgery.³⁶ Scheer et al.⁴² showed that elderly patients (> 65 years) who underwent 3-column posterior subtraction osteotomies for correction of spinal deformity were more likely to reach a minimum clinically important difference compared with younger patients (< 45 years) in terms of 1- and 2-year Physical Component Scores and Scoliosis Research Society pain and function scores. This again emphasizes the beneficial role of surgery in elderly patients, despite the incidence of complications.

In this large retrospective study of 8432 patients, we demonstrated that increasing age was associated with postoperative complications including hemorrhage, infection, PE, and refusion. Here, we have emphasized the importance of age predicting hemorrhage

development, allowing clinicians to better anticipate such morbidity in older persons. Our results correlate with several studies⁴³⁻⁴⁷ that have reported age-associated increase in incidence of complications after spinal surgeries. A retrospective study by Smith et al.³⁶ evaluating outcomes in 206 adult patients with scoliosis showed a 4- and 5-fold increase in the number of minor complications (eg, airway edema, mild pleural effusion, cerebro-spinal fluid leak, venous thrombosis, superficial infection) and major complications (eg, deep wound infection, excessive blood loss, hemothorax, PE myocardial infarction, nerve root injury), respectively, in the oldest age cohort (65–85 years) compared with the youngest (25–44 years). Another study by Carreon et al.³⁵ illustrated that the prevalence of major complications (wound infection, pneumonia, renal failure, neurologic deficit, myocardial infarction) increased with age in 101 patients aged 65 years and older undergoing spinal surgery. These studies suggest that age can potentially increase the baseline risk for surgical complication and should be included in the preoperative risk assessment when counseling elderly patients.

Infection and hemorrhagic complications are common concerns in major spinal procedures. In our study, increasing age was associated with increased risk of infection. This increased risk could be associated with our higher comorbidity index in older patients. This correlates with reported increase in surgical complications (pulmonary, bleeding/hematoma, renal, cardiac, infectious, neurologic, and thromboembolic) in association with medical comorbidity.⁴⁰ Elderly patients are more likely to present with more comorbidities, which increases their baseline risk of postoperative complications. The extent of surgical complexity, surgical approach, and reoperations can also influence the incidence of adverse outcomes.⁴⁸ Older patients often present with advanced and more challenging spinal diseases combined with decreased bone integrity, degenerative changes, kyphotic deformities, and increased rigidity of spinal deformity.^{23,49} These cumulative spinal diseases can all increase operating room time, blood loss, and hospital length of stay. Furthermore, there can be bleeding risk related to medications common to the aging population that interfere with the coagulation cascade as well as bleeding events related to age-related tissue integrity changes. Consequently, there is a potential increase in the baseline risk of surgical complications after primary fusion for scoliosis.

Differences in baseline risk factors such as gender, hypertension, or smoking have previously been shown to influence the rate of hemorrhagic complications.⁵⁰⁻⁵² Our study demonstrated that age is a significant contributor to hemorrhagic complications. Patients should therefore be evaluated for risk of hemorrhage with standard risk factors such as hypertension, bleeding disorders, blood vessel abnormalities, and use of anticoagulants to minimize the confounding effects of these variables on surgical complications. Based on our findings, age should be included in the pre-operative risk assessments in patients with scoliosis considering surgery. Duke University Medical Center has recently adopted a Perioperative Optimization of Senior Health Program with the aim of improving outcomes in elderly patients (>65 years) undergoing lumbar spinal fusion. In this program, a geriatrician-led team in addition to the neurosurgical staff evaluate patients daily throughout their hospital stay to manage medical comorbidities, treat pain, prevent delirium, and coordinate rehabilitation. Our preliminary results show a significant reduction in the incidence of postoperative complications (urinary tract infection and pneumonia), hospital

length of stay, and 30-day readmission rates. Such a highly customized intervention has the potential to be beneficial to elderly patients undergoing spinal surgery, and the present study supports the necessity of developing such novel approaches to surgical intervention in the elderly.

In balancing the risk of hemorrhage, clinicians must consider the risk of PE, a complication that is often reported after spinal surgeries. The incidence of PE in adult patients undergoing spinal surgery is confounded by various attributable factors such as age, obesity, gender, and tobacco consumption, which increase the baseline risk after spinal surgeries.⁵³⁻⁵⁷

Controversy continues regarding the use of systemic anticoagulant in the prevention of PE, given the risk of bleeding in the postoperative phase.⁵⁶⁻⁵⁹ Despite the controversy, patients should be evaluated on an individual basis, with inclusion of attributable risk factors for PE in the decision algorithm for preventive measures after major spinal surgery. Providers should continue to encourage early ambulation and the use of sequential compression devices to prevent postoperative deep venous thrombosis/PE.

Reoperation (or refusion) rates have been downtrending over the past several decades as surgical techniques become more advanced and minimally invasive, despite the confounding factor that revision rates undoubtedly increase over time. Some variability exists in reported rates of reoperation, partly as a result of surgical approaches and the broad spectrum of associative postoperative complications. Luhmann et al.²⁹ documented a 3.9% reoperation rate with an average follow-up of 5.7 years and Richards et al.³⁹ reported a rate of 12.37% within the first 5 years of surgery. Our study showed a lower reoperation rate of 2.8%, with an average of 1.8 ± 1.79 years to reoperation. The broad spectrum of causes for reoperation can account for the variability in reported rates. Infection, pseudarthrosis, pain, and symptomatic implants are among the leading causes of reoperation after primary fusion for adult scoliosis.^{29,33,39} Our results showed a nonlinear relationship between age and revision, with the highest revision rate in the middle age group. We believe this can be attributed to predicted years left in a person's life incentivizing reoperation because there would be a hypothetical greater number of years remaining to benefit from such revision. Our study does not support age as the only factor contributing to risk of revision. Notwithstanding the nonlinear relationship, given the increased odds of surgical complications with increasing age,^{3,35,60,61} and medical comorbidities,⁴⁰ elderly patients are at greatest risk for complication-driven reoperations. This has negative implications on patients' quality of life and health care resource use. The cost associated with reoperation was illustrated by McCarthy et al.⁶² in a study of 484 patients undergoing spinal surgery for adult spinal deformity. These investigators reported an increase of more than 70% in the average cost as a result of readmission for spine-related operations. This potentially creates an added financial burden on health care institutions, providers, and patients. With the constant advancement in technology used in spinal surgeries and the minimal invasiveness of the procedures, the occurrence of fewer postoperative complications will drive down the need for reoperations in some patients.

Mortality associated with spinal surgery remains a devastating adverse outcome, with several confounding variables that can affect the overall incidence. Despite the rarity of this phenomenon, the risk factors for mortality are an essential component of presurgical

evaluation to optimize patient care. Our study showed a trend toward increased incidence of mortality with increasing age. Our findings are similar to a larger study of 108,419 patients by Smith et al.⁴⁸ evaluating the rates and causes of mortality associated with spine surgery. These investigators showed that the mortality among patients aged 21 years or older was almost double the rate in patients younger than 21 years (2.0 vs. 1.3 deaths per 1000 patients). When stratified by age groups, the same study illustrated a dramatic age-associated increase in mortality: 0.9 and 34.3 deaths per 1000 patients, aged 20–39 and 90 years, respectively. However, other variables such as the existence of medical comorbidities can increase the mortality rate after spinal surgery. A recent study of 87,162 cases of deformity (scoliosis: $n = 50,553$) from the Scoliosis Research Society by Shaffrey et al.⁶³ demonstrated an overall mortality of 1.5 per 1000 cases, with respiratory (36.6%), cardiovascular events (24.4%), and sepsis (9.2%) being the 3 most common causes. Based on these studies, the risk of mortality should be assessed preoperatively using variables such as patient age and the existence of medical comorbidities. Notwithstanding the relatively low incidence of mortality in spine surgery, continuous efforts to improve patient safety and optimize clinical outcomes should be encouraged.

This study has several limitations that must be acknowledged. First, the use of ICD-9 codes inherently depends on accurate coding, which leads to intrinsic poor reliability. However, this coding system is commonly used to classify diagnoses and every effort is made to ensure accuracy, making the coding construct an appropriate (although not perfect) approach to analysis. Beyond this, clinical factors such as disease severity and health care quality of life are not in the dataset, nor does this study account for the types of surgical approaches, as mentioned previously. Radiographic factors including spinopelvic modifiers (sagittal vertical axis, pelvic tilt, pelvic incidence/lumbar lordosis mismatch) were not available. In addition, our study could not capture variables such as smoking history and obesity, which are known factors that increase baseline risk of PE. Furthermore, operative effect could not be determined because metrics such as Scoliosis Research Society and quality of life scores are not included in the database. Also, because patients were selected using diagnosis and procedure codes, miscoding may be present, and because readmission data were used to assess complications, the analysis may miss the perioperative hematomas and superficial infections of such surgeries. We attempted to reduce this inaccuracy by using ICD-9 and Current Procedural Terminology codes, allowing for greater data accuracy. This study was retrospective and nonrandomized. Despite these limitations, we believe that our study provides a valuable addition to the literature investigating and quantifying the impact of advancing age on outcomes after primary spinal fusion for adult scoliosis.

Conclusions

As health care costs continue to increase, increasing attention is focused on reducing surgical complications in patients undergoing spine surgery for scoliosis. In this retrospective cohort analysis, age was associated with increased risk of hemorrhagic events, PE, infection, and reoperation. With the aging population, the role of patient age on postoperative healing and outcomes after repair of adult scoliosis deserves deeper investigation. Future studies should analyze the differences in mortality in older persons based on type of surgery to optimize the approach to surgically repairing adult scoliosis in

the aging population. Overall, we find that physicians should work with elderly patients to balance the anticipated symptomatic relief from surgery with the age-associated increased risk of surgical complications in the decision algorithm when considering surgical intervention for scoliosis.

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Abbreviations and Acronyms

CI	Confidence interval
ICD-9-CM	<i>International Classification of Diseases, Ninth Revision, Clinical Modification</i>
OR	Odds ratio
PE	Pulmonary embolism

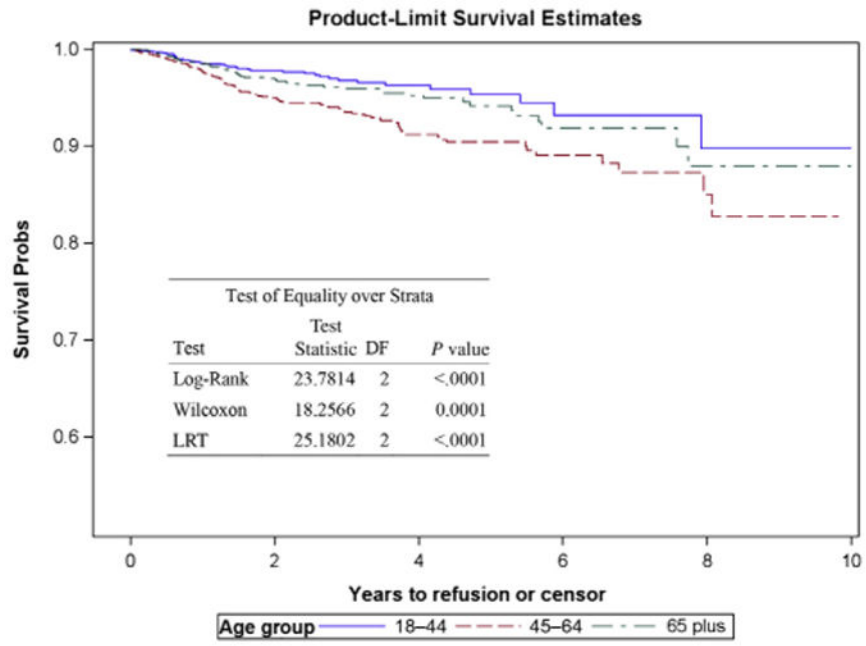


Figure 1. Kaplan-Meier survival estimates for refusion stratified by age groups: 18–44 years; 45–64 years; 65+ years.

Table 1

Demographics by Age Group

	Total	Age Group			P Value
		18-44 years	45-64 years	65+ years	
Total, number (col%)	8432 (100)	2164 (100)	4038 (100)	2230 (100)	< 0.0001
Age, mean (standard deviation)	53.3 (18.04)	27.2 (9.17)	56.5 (5.34)	73.0 (5.47)	< 0.0001
Commercial insurance	5633 (66.81)	1773 (81.93)	3860 (95.59)	00 (00.0)	
Medicaid	604 (7.16)	391 (18.07)	142 (3.52)	71 (3.18)	
Medicare	2195 (26.03)		36 (0.89)	2159 (96.82)	< 0.0001
Gender					
Male	2268 (26.90)	649 (29.99)	986 (24.42)	633 (28.39)	
Female	6164 (73.10)	1515 (70.01)	3052 (75.58)	1597 (71.61)	< 0.0001
Charlson Score, number (col%)					
0	5144 (61.01)	1735 (80.18)	2423 (60.00)	986 (44.22)	< 0.0001
1	1888 (22.39)	324 (14.97)	952 (23.58)	612 (27.44)	< 0.0001
2	835 (9.90)	74 (3.42)	411 (10.18)	350 (15.70)	< 0.0001
3	565 (6.70)	31 (1.43)	252 (6.24)	282 (12.65)	< 0.0001
Follow-up days, mean (standard deviation)	669.6 (664.31)	671.1 (653.9)	644.3 (636.72)	713.9 (718.96)	0.0004

col%, Column percentage.

Table 2

Outcomes by Age

	Total	Age Group			P Values
		18–44 years	45–64 years	>65 years	
Total patients, number (col%)	8432 (100)	2164 (100)	4038 (100)	2230 (100)	0.0004
Hemorrhage within 90 days, number (col%)	335 (3.9)	56 (2.59)	178 (4.41)	101 (4.53)	0.0006
Infections within 90 days, number (col%)	950 (11.27)	200 (9.24)	456 (11.29)	294 (13.18)	0.0002
Pulmonary embolism within 90 days, number (col%)	262 (3.1)	42 (1.94)	117 (2.90)	103 (4.62)	< 0.0001
Pneumonia within 90 days, number (col%)	884 (10.48)	203 (9.38)	357 (8.84)	324 (14.53)	< 0.0001
Death in 90 days, number (col%)	27 (0.32)	3 (0.14)	11 (0.27)	13 (0.58)	0.0254
Refusion number (col%)	242 (2.8)	44 (2.03)	142 (3.52)	56 (2.51)	0.0019
Years to refusion or censor, mean (standard deviation)	1.8 (1.79)	1.8 (1.78)	1.7 (1.70)	1.9 (1.094)	0.0001

col%, Column percentage.

Table 3
Logistic Regression: Effect of Age (Per 5-Year Increments) on Complication Rate and Refusion Within 90 Days of Surgery

	Bivariate		Multivariate	
	Estimate (95% Confidence Interval)	P Value	Estimate (95% Confidence Interval)	P Value
Hemorrhagic complication	1.05 (1.02–1.09)	0.0021	1.06 (1.01–1.11)	0.0196
Infectious complication	1.04 (1.02–1.06)	< 0.0001	1.04 (1.01–1.07)	0.0053
Pulmonary embolism	1.11 (1.07–1.16)	< 0.0001	1.09 (1.03–1.16)	0.0031
Refusion or reoperation	–	–	1.07 (1.02–1.13)	0.0103

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