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Int J Spine Surg published online 9 October 2024
https://www.ijssurgery.com/content/early/2024/10/09/8653

This information is current as of October 12, 2024.

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The International Journal of Spine Surgery
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International Journal of Spine Surgery Publish Ahead of Print, published on October 9, 2024 as doi:10.14444/8653

International Journal of Spine Surgery, Vol. 00, No. 0, 2024, pp. 1–7
https://doi.org/10.14444/8653
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Baseline Neck Disability Index and Patient-Reported Outcomes Measurement Information System Physical Function Predict Postoperative Return to Normal in Cervical Spine Surgery

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ABSTRACT

Background: Recent studies assessing the importance of various preoperative factors on postoperative outcomes following spine surgery have uncovered several important variables that influence subjective and objective outcomes following cervical spine surgery, but it is still unclear which patients are most likely to benefit from operative management.

Purpose: The objective of this study was to assess whether preoperative patient-reported outcome measures (PROMs) can be used to predict which patients achieve "normal" levels of pain and function after surgery.

Study Design: This was a prospective cohort study.

Patient Sample: This study included all adult patients undergoing cervical spine surgery by 1 of 7 senior spine surgeons at our institution between 2016 and 2018. Of the 164 patients who were eligible for 6-month follow-up at the time that study data were collected, 139 had available follow-up data and were included in our analysis.

Outcomes Measures: Patients completed the Neck Disability Index (NDI) as well as the Patient-Reported Outcomes Measurement Information System (PROMIS) Physical Function (PF) and Pain Interference computer adaptive tests preoperatively and at 6 months postoperatively.

Methods: Patients who achieved postoperative patient-acceptable symptom state (PASS) for NDI (≤17) and the normative mean (50) for PROMIS were identified. The relationship between preoperative PROMs and the probability of achieving PASS and the normative mean was assessed.

Results: One hundred thirty-nine patients met inclusion criteria with diagnoses of myelopathy (n = 36), radiculopathy (n = 48), and myeloradiculopathy (n = 49). For NDI, a 1-point worsening in the preoperative score resulted in an OR of achieving PASS of 0.96 ($P < 0.001$) in the overall population. This association held true for patients with radiculopathy (OR 0.96; $P = 0.022$) but not myelopathy (OR 0.98; $P = 0.35$). For PROMIS PF, a 1-point improvement in the preoperative score resulted in an OR of achieving the normative mean of 1.10 ($P < 0.001$). This association held true for patients with radiculopathy (OR 1.14; $P = 0.033$) but did not reach statistical significance for patients with myelopathy (OR 1.03; $P = 0.515$).

Conclusions: Preoperative PROMs can predict postoperative benefit for patients undergoing cervical spine surgery, with worse baseline function associated with a lower likelihood of attaining PASS for NDI and the normative mean for PROMIS PF, especially for patients with radiculopathy.

Clinical Relevance: Baseline symptoms and function, including myelopathy or radiculopathy-dominant symptoms and preoperative PROMs, may predict postoperative outcomes.

Level of Evidence: 3.

Cervical Spine

Keywords: cervical spine, PROMs, myelopathy, radiculopathy, PROMIS, PASS

INTRODUCTION

Degenerative disease of the cervical spine is 1 of the most common pathologies encountered by spine surgeons. When conservative treatments like physical therapy and steroid injections fail, surgical treatment is often indicated to alleviate refractory pain, radiculopathy, and myelopathy. Among the various

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surgical options used to treat degenerative cervical pathology, anterior cervical discectomy and fusion (ACDF) is the most common, with roughly 132,000 ACDFs being performed annually in the United States between 2006 and 2013,[1] and far more are likely to be performed in the current decade. Surgical treatments for cervical degenerative diseases have a long track record of successful outcomes.[2–9] Despite this track record, postoperative pain, disability, and dissatisfaction remain significant issues following surgical treatment of cervical spine pathology.[10–12]

In recent decades, there has been an increased effort to study and identify preoperative predictors of adverse outcomes following cervical spine surgery. Such studies are crucial not only for uncovering potentially modifiable factors that influence outcomes but also for driving surgical indications by identifying the patient populations that are most likely to achieve a benefit from surgical intervention. One important area of focus is the study of how preoperative symptom severity and disability level impact postoperative outcomes, which to date has shown mixed results. Three prior studies have reported that preoperative disability portends worse outcomes following surgery for myelopathy.[13–15] Conversely, Fehlings et al and the AO North America multicenter study noted no difference in outcomes when stratifying patients by baseline functional status. In contrast to these prior studies, they note that patients with severe myelopathy actually experienced the greatest improvement in modified Japanese Orthopaedic Association (mJOA) scores.[16] Other preoperative factors, including axial neck pain,[17,18] increased preoperative cord signal,[19] ossification of the posterior longitudinal ligament,[20] duration of symptoms,[21,22] advanced age,[23,24] and lower preoperative mJOA score,[24] have also been identified as predictors of poor postoperative outcomes.

Recent studies assessing the importance of various preoperative factors on postoperative outcomes following spine surgery have uncovered several important variables that influence subjective and objective outcomes following surgery. However, additional studies are needed in order to further characterize the patient populations that are most likely to benefit from operative management. While studies have established that patients with poor preoperative function can benefit from surgery, to what extent patients can return to a "normal" level of function remains unknown. In the current study, we assessed how preoperative patient-reported outcomes measures (PROMs), namely Neck Disability Index (NDI) and Patient-Reported Outcomes Measurement Information System (PROMIS), impact the probability of achieving a satisfactory level of function postoperatively.

MATERIALS AND METHODS

Study Design and Patient Population

Institutional Review Board approval was obtained prior to the initiation of the study (number 2015–363). Informed consent was obtained. This study included all adult patients undergoing cervical spine surgery by 1 of 7 senior spine surgeons at our institution between 2016 and 2018. Inclusion criteria were (1) age ≥18 years, (2) English speaking, and (3) undergoing cervical spine surgery. Exclusion criteria included (1) non-English speaking, (2) undergoing surgical stabilization for cervical instability secondary to trauma, and (3) infection.

Outcome Measures and Analysis

Patients completed the NDI as well as the PROMIS Physical Function (PF) and Pain Interference (PI) computer adaptive tests preoperatively and at 6 months postoperatively. For the NDI, the threshold of reaching a satisfactory level of function was determined using the patient acceptable symptom state (PASS). Unlike minimal clinically important difference (MCID), which is the minimal change in score that is perceptible by the patient, PASS is defined as the target value on a PROM scale beyond which patients deem themselves to have attained an acceptable outcome. A recent study determined the PASS threshold for NDI as being ≤17.[25] For the PROMIS subscales, the normative mean value of 50 was used as the threshold for attaining an acceptable postoperative state. Using the Assessment Center (www.assessmentcenter.net), preoperative and postoperative NDI and PROMIS PF and PI surveys were administered to the patients enrolled in the current study. Questions were asked in a randomized order to avoid bias associated with question order and survey fatigue.

All statistical analysis for this study was performed using STATA 15.0 (Stata Corp, College Station, TX, USA). Descriptive statistics were used to describe demographic and clinical characteristics. X^2 tests were used to identify differences between groups in the proportion of patients achieving the normative mean and PASS. Univariate logistic regressions were used to determine the odds of achieving the binary outcomes under study (attaining PASS vs not attaining pass;

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attaining normative mean vs not attaining normative mean) associated with incremental 1-point increases in preoperative NDI and PROMIS scores in the overall population and diagnosis subgroups (myelopathy and radiculopathy). A 2-sided type I error rate of 0.05 was used to determine statistical significance. The proportions of patients achieving PASS and the normative mean were determined, with preoperative outcome scores stratified by quintiles for PROMIS and levels of disability for NDI.[26]

RESULTS

Of the 164 patients who were eligible for 6-month follow-up at the time that study data were collected, 139 had available follow-up data and were included in our analysis. Six-month follow-up was selected as the minimum, as multiple studies have demonstrated that PROMs plateau by 3–6 months following spine surgery.[27–30] Of these 139 patients, 83 (59.7%) were men, and the mean age was 56.4 years (range, 24–85). Patients had differing indications for surgery, including isolated radiculopathy (n = 48, 34.5%), isolated myelopathy (n = 36, 25.9%), or myeloradiculopathy (n = 49, 35.3%) (Table 1). The anterior approach was used in 102 patients (73.4%), while the posterior approach was utilized in 37 (26.6%).

Impact of Preoperative PROMS on Achieving PASS or the Normative Mean

The proportion of patients who met NDI PASS with preoperative NDI scores of 0 to 4 (no disability), 5 to 15 (mild disability), 15 to 24 (moderate disability), 25 to 34 (severe disability), and >34 (complete disability) is illustrated in Figure 1. When stratified by baseline level of disability, the proportion of patients reaching PASS was 83%, 100%, 80%, 57%, and 52% for baseline NDI 0 to 4, 5 to 15, 15 to 24, 25 to 34, and >34, respectively. This difference between groups was statistically significant (P = 0.005). In Figures 2 and 3, the proportion of patients who met the normative mean for PROMIS PF and PI, respectively, is shown as a function of the preoperative PROMIS quintile score. For PROMIS PF, the proportion of patients reaching the normative threshold was 62%, 46%, 30%, 33%, and 26% for baseline PF 47.7 to 66.2, 43.3 to 47.2, 40.1 to 43.1, 34.7 to 40.0, and 23.5 to 34.6, respectively. This difference between groups was statistically significant (P = 0.035). For PROMIS PI, the proportion of patients reaching the normative threshold was 69%, 48%, 70%, 64%, and 74%. This difference between groups was not statistically significant.

For NDI, a 1-point increase (worse NDI) in the preoperative score resulted in OR of achieving PASS (NDI ≤ 17) of 0.96 (P < 0.001). This association held true for patients with radiculopathy (OR 0.96; P = 0.022) but did not reach statistical significance for patients with myelopathy (OR 0.98; P = 0.35). For PROMIS PF, a 1-point increase (improved PROMIS) in the preoperative score resulted in OR of achieving the normative mean (PROMIS ≥ 50) of 1.10 (P < 0.001). This association held true for patients with radiculopathy (OR 1.14; P = 0.033) but did not reach statistical significance for patients with myelopathy (OR 1.03; P = 0.515)

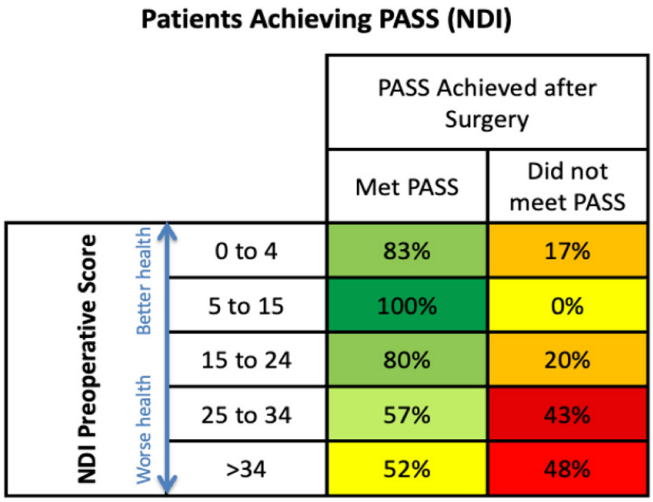

Figure 1. Proportion of patients meeting NDI PASS shown as a function of preoperative NDI. Differences between these groups were statistically significant (P = 0.005). NDI, Neck Disability Index; PASS, patient acceptable symptom state.

Table 1. Association between preoperative outcomes and postoperative clinical benefit.

	PROMIS PF		PROMIS PI		NDI	
Surgery Indication	**Preoperative**	**Postoperative Improvement**	**Preoperative**	**Postoperative Improvement**	**Preoperative**	**Postoperative Improvement**
Radiculopathy	39.2 (8.1)	5.2 (8.0)	60.4 (7.8)	−8.9 (10.8)	29.4 (22.0)	13.4 (17.8)
Myelopathy	41.7 (7.4)	9.0 (9.4)	61.9 (6.0)	−10.3 (9.5)	39.2 (2.2)	22.2 (17.6)
Myeloradiculopathy	43.0 (8.4)	5.6 (7.2)	59.9 (7.3)	−6.9 (9.1)	31.6 (19.5)	14.4 (14.5)

Abbreviations: NDI, Neck Disability Index; PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function; PROMIS PI, Patient-Reported Outcomes Measurement Information System Pain Interference.
Note: For Neck Disability Index, postoperative improvements reflect a decrease in score, as lower scores reflect lower disability.

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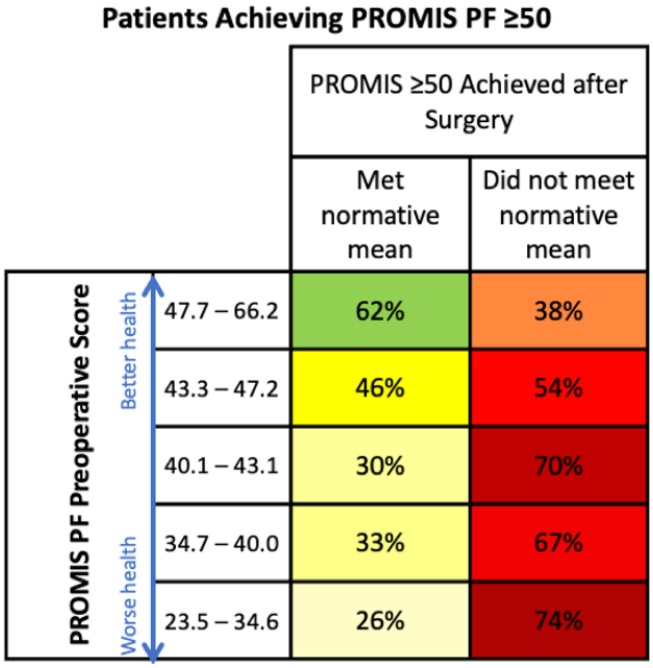

Figure 2. Proportion of patients attaining the normative means (≥50) for PROMIS PF shown as a function of preoperative PROMIS PF quintile. Differences between these groups were statistically significant (P = 0.035). PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function.

(Table 2). PROMIS PI did not demonstrate statistically significant correlations between worse baseline scores and achieving postoperative PASS and the normative mean.

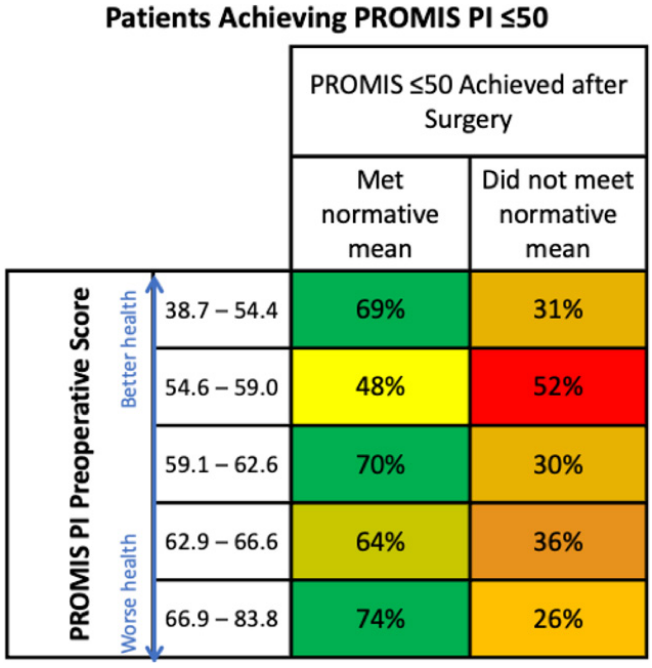

Figure 3. Proportion of patients attaining the normative means (≤50) for PROMIS PI shown as a function of preoperative PROMIS PI quintile. Differences between these groups were not statistically significant. PROMIS PI, Patient-Reported Outcomes Measurement Information System Pain Interference.

Table 2. Association between preoperative diagnosis and outcome.

Outcome	OR	95% CI	*P*
Overall			
NDI	0.96	0.94, 0.98	<0.001
PROMIS PI	1.04	0.99, 1.09	0.144
PROMIS PF	1.1	1.04, 1.16	<0.001
Radiculopathy			
NDI	0.96	0.92, 0.99	0.022
PROMIS PI	1.03	0.95, 1.12	0.491
PROMIS PF	1.14	1.01, 1.29	0.033
Myelopathy			
NDI	0.98	0.94, 1.02	0.35
PROMIS PI	1.06	0.96, 1.18	0.262
PROMIS PF	1.03	0.95, 1.11	0.515

Abbreviations: NDI, Neck Disability Index; PASS, patient acceptable symptom state; PF, Physical Function; PI, Pain Interference; PROMIS, Patient-Reported Outcomes Measurement Information System.

DISCUSSION

While the clinical benefit of surgical intervention for refractory pain or myelopathy associated with degenerative cervical spine disorders has been clearly demonstrated, a significant proportion of patients still experience suboptimal outcomes following surgery. Improving our understanding of the extent to which preoperative factors impact postoperative outcomes is a critical step for surgeons in indicating patients for surgery and counseling them about the expected prognosis. In the current study, we assessed the impact of preoperative NDI and PROMIS PF and PI scores on the probability of attaining postoperative acceptable levels of function, using PASS for NDI and the normative mean for PROMIS. We found that worse preoperative function was associated with a lower probability of returning to "normal" postoperatively. When assessed as a function of preoperative diagnosis, we demonstrated that while this relationship holds true for patients with primarily radicular symptoms, there is no significant relationship between baseline preoperative NDI or PROMIS score and the probability of returning to "normal" for patients with primarily myelopathic symptoms.

While there are numerous studies that have assessed outcomes following cervical spine surgery, there are a limited number of studies utilizing preoperative symptoms or disability level to predict the degree of postoperative function, disability, or likelihood of obtaining a clinically significant improvement in symptoms. One example of a preoperative symptom that has been extensively studied with respect to its impact on postoperative outcomes is neck vs radicular arm pain in patients with cervical spine pathology.[17,18,31] Though this topic is well studied, the results are fairly mixed. While the majority of studies have identified neck disability as a predictor of poor outcomes following

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ACDF,[32–34] others have found the opposite, namely that higher levels of preoperative neck pain and disability are positive predictors of treatment success.[35,36] These mixed results may be partially explained by the fact that various studies use different methods of characterizing surgical benefit, such as improvement from baseline and overall postoperative PROMs. Though the etiology of these differences is not completely clear, the results of the current study appear to corroborate the findings of the former studies described here, in which a lower degree of preoperative disability is associated with a better postoperative outcome and a higher probability of achieving a "normal" level of function.

Interestingly, while we found a relationship between better preoperative PROMs and the likelihood of achieving a clinically meaningful postoperative outcome for patients with radiculopathy, this relationship did not hold true for patients with predominantly myelopathic symptoms. While the explanation for this outcome is not completely understood, it may be due to differences in the natural history and treatment goals for these 2 different conditions. Because of the presumed progressive and stepwise nature of myelopathic symptoms, surgical treatment for myelopathy is largely focused on preventing the worsening of this condition, and postoperative improvements have been thought to be less predictable. The mixed results seen in this population are likely reflective of the less predictable response to surgery seen in patients with myelopathy. While several studies showed a correlation between greater preoperative disability and worse postoperative outcomes,[13–15] others reported the opposite.[16,25] For example, Fehlings et al found that patients with myelopathy achieved MCID for Nurick, NDI, SF-36, and mJOA.[16] Additionally, Goh et al found that significant portions of patients undergoing surgical treatment for myelopathy attain MCID using the Japanese Orthopaedic Association score.[37]

One important point to address is that patients with no preoperative disability (NDI 0–4) had a nonsignificant trend toward a lower chance of achieving PASS than those with mild preoperative disability (NDI 5–14). While we do not recommend the use of NDI as a screening tool for surgical candidates, this finding may be important for preoperative counseling. In patients with no preoperative disability, there is a slightly lower chance of achieving PASS. However, this likely varies on a patient-to-patient basis. Because disability is a subjective experience, patients with severe symptoms that justify surgical intervention may not have a significant disability if they are highly resilient and vice versa. Also, in specific instances like myelopathy, symptoms may be minimal despite severe cord compression. These patients may elect to undergo surgical intervention despite no disability in order to prevent future deterioration.

This study had many limitations. First, while our sample size is comparable to prior studies on this topic, it limits a robust assessment of subgroups due to limited power. Second, different patients included in this study were treated using either the anterior or posterior approach, which was not controlled for and may have had subtle impacts on the results, as these patients may have different recovery trajectories at our final endpoint. Third, the follow-up time of 6 months limits the assessment of any long-term differences in patient outcomes. Fourth, although the outcome measures used in this study are well-validated, they were not devised specifically for the assessment of myelopathy. Therefore, they may not have been as sensitive in detecting improvements in myelopathic symptoms, which may explain why no significant results were identified for patients with myelopathy. It is possible that different results would be found with the use of the Japanese Orthopedic Association myelopathy assessment. Future studies should focus on patient-specific assessments of satisfaction to determine individualized thresholds for PASS based on preoperative symptoms and preoperative symptom severity.

CONCLUSIONS

To our knowledge, this is the first report assessing the impact of preoperative PROMs on the ability for patients to return to "normal" functional levels after cervical spine surgery. Here, we show that preoperative NDI and PROMIS PF are predictive of postoperative benefit, with patients at higher levels of preoperative function being more likely to attain this normative threshold postoperatively. This held true for the overall cohort, as well as for patients with the underlying diagnosis of radiculopathy, but not myelopathy. These results provide invaluable insights for patients and surgeons alike in better understanding the prognosis for patients undergoing operative management for cervical degenerative disease, especially patients with primarily radicular symptoms.

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Funding: Virginie Lafage received a grant (paid to her institution) from CSRS for the present manuscript. Sravisht Iyer reports support from Innovasis.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

Disclosures: Sravisht Iyer reports consulting fees from Stryker; payment/honoraria from Globus Medical; participation on a Data Safety Monitoring or advisory board for Healthgrades; and other financial/nonfinancial interests in HS2 LLC. Todd J. Albert reports grants from JP Medical Publishers, Theime Medical Publishers, Springer, and Elsevier; royalties/licenses from Biomet (now Zimmer Biomet) and DePuy Synthes Spine; consulting fees from NuVasive; and other financial/nonfinancial interests in Back Story LLC, Innovative Surgical Designs, Inc, InVivo Therapeutics, Spinicity, CytoDyn Inc., Paradigm Spine LLC, HS2 LLC, Stathspey Crown, Parvizi Surgical Innovation LLC, Surg.IO LLC, Care Equity, Augmedics, Morphogenesis, Precision Orthopedics, Pulse Equity, and Physician Recommended Nutriceuticals. Darren R. Lebl reports royalties from NuVasive and Stryker; consulting fees from DePuy Synthes and Stryker; participation on an advisory board for Remedy Logic; and ownership interest in HS2 LLC, ISPH II LLC, Remedy Logic, Vestia Ventures MiRus Investment LLC, Viseon, and Woven Orthopedic Technologies. Virginie Lafage reports a grant from the International Spine Study Group (paid to her institution); royalties/licenses from Nuvasive; consulting fees from Globus Medical and Alphatec; payment/honoraria for lectures, presentation, speakers bureaus, manuscript writing, or education events from J&J, Stryker, and Implanet; and leadership roles for the International Spine Study Group and Scoliosis Research Society. Han Jo Kim reports grants/contracts from ISSGF (paid to institution); royalties/licenses from Zimmer Biomet, K2M/Stryker, and Acuity Surgical; consulting fees from NuVasive; participation on a Data Safety Monitoring or advisory board for Vivex Biology and Aspen Medical; and other financial/nonfinancial interests in AO Spine. The remaining authors have nothing to disclose.

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