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Original Research

Reversal of the Halo Effect: Prolonged Participation in Comprehensive Care for Joint Replacement Negatively Impacts Revision Metrics

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ABSTRACT

Background: The downstream regional effect of the Comprehensive Care for Joint Replacement (CJR) program on care pathway-adjacent patients, including revision arthroplasty patients, is poorly understood. Prior studies have demonstrated that care pathways targeting primary total joint arthroplasty may produce a halo effect, impacting more complex patients with parallel care pathways. However, neither the effect of regional referral changes from CJR nor the durability of these positive changes with prolonged bundle participation has been assessed.

Methods: Blinded data were pulled from electronic medical records. Primary analyses focused on the effect of CJR participation from 2015 (baseline) to 2020 (final participation year) at a tertiary care safety-net hospital. Patient demographics were evaluated using multivariate analysis of variance and chi-square calculations between procedure types over time.

Results: Patients who underwent revision total knee arthroplasty (N = 376) and revision total hip arthroplasty (N = 482) were included. More patients moved through the revision-care pathway over the participation period, with volume increasing by 42% over time. Patients became more medically complex: the Charlson comorbidity index increased from 3.91 to 4.65 ($P = .01$). The mean length of stay decreased from 5.14 days to 4.50 days ($P = .03$), but the all-cause complication (8.3%-15.2%; $P = .02$) and readmission rates (13.6%-16.6%; $P = .19$) increased over time.

Conclusions: Despite care pathway improvements over 5 years of CJR participation, revision patients did not display clear benefits in quality metrics but demonstrated a considerable increase in volume and medical complexity over time. The care of these patients may supersede even thoughtfully implemented care pathways, especially when referral burden increases, as may be prone to happen in regional, financial risk-conferring value-based programs. Understanding the impact of mandatory bundled payment programs like CJR on the care of arthroplasty patients regionally will be essential as value-based programs evolve.

Introduction

As total joint arthroplasty (TJA) continues to increase in utilization, recent health policy changes from the Centers for Medicare and Medicaid Services (CMS) have targeted these operations as a potential for substantial cost savings due to their high volume and perceived opportunities for standardization [1,2]. As with many policy decisions, unintended consequences may alter the downstream impact of the new policy. Participation in the Comprehensive Care for Joint Replacement (CJR) program, a major value-based bundle program from CMS, is regional and mandatory, impacting all hospitals, providers, and patients in specific metropolitan areas [3]. This arrangement may exert unintended selection pressure, influencing systems to avoid caring for patients at a higher risk of complications or those who will need high resource utilization, so-called "bundle busters" [4,5]. In fact, recent data have identified

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that unclear guidelines from CMS have promoted higher concentrations of medically complex patients in safety net hospitals, while lower-risk patients are either being shunted into outpatient pathways or to other centers [5,6].

Moreover, the downstream impacts of participation in bundled programs on the care of revision arthroplasty patients have not been well understood. Due to the high degree of procedural variation, revision TJA (RTJA) may be even more prone to large swings in outcomes and cost. Previous work has demonstrated though bundled payment models might not be cost favorable for managing revision patients, care pathway changes that target primary TJA may have a halo effect (ie, unintended benefit from an intervention outside of the intended target group; eg, an intervention focusing on CJR patients helping non-CJR patients undergoing primary total joint replacement) or creep effect (ie, unintended benefit to other services or a separate procedure group; eg, an intervention for primary arthroplasty cases "creeping" into revision arthroplasty, hip fracture or oncology cases via automatic implementation and utilization of similar protocols by overlapping care teams utilizing enhanced recovery after surgery programs such as same day physical therapy, pain management protocols and preferential home discharge planning) favorably impacting quality metrics for these more complex patients via parallel care pathways [7,8]. However, as more complex patients began shifting into these tertiary care and safety-net settings, the sustainability and durability of this impact were poorly characterized.

Previous data demonstrated maintained quality metrics in patients who underwent a primary TJA over the participation period despite worsening medical complexity [6]. We hypothesized that RTJA patients would benefit from our system-wide care program with respect to several core quality metrics with a durable halo effect. As such, the objective of this study was to 1) understand the associated demographics within our RTJA patient population and 2) understand the impact of prolonged regional CJR participation on the quality metrics (ie, length of stay [LOS], complications, readmissions, and discharge to home) for patients undergoing RTJA in our tertiary care safety-net hospital.

Material and methods

After institutional review board approval, blinded data were obtained from our internal electronic medical records (EMR; Epic Systems, Madison, Wisconsin) using System Applications and Products (BusinessObjects XI, San Jose, CA). Cases were included if they were assigned the following Current Procedural Terminology codes: 27134 (Revision Total Hip Arthroplasty, Both Components), 27137 (Acetabular Component Revision), 27138 (Femoral Component Revision), 27486 (Revision Total Knee Arthroplasty, Single Component), and 27487 (Revision Total Knee Arthroplasty, Both Components). Cases were excluded if they were related to joint infection. Time points were defined by payer year (PY) corresponding to the CJR: 2015 (October 01, 2015-December 31, 2015), PY1 (April 01, 2016-September 30, 2016), PY2 (October 01, 2016-September 30, 2017), PY3 (October 01, 2017-September 30, 2018), PY4 (October 01, 2018-September 20, 2019), and PY5 (October 1, 2019-September 30, 2020).

Data analysis

Data were analyzed using the Statistical Package for Social Sciences Version 28 (SPSS, Inc., Chicago, IL). Continuous data (ie, age, body mass index [BMI], Charlson comorbidity index [CCI], LOS) were reported as means and standard deviations and categorical data (ie, readmissions, complications, home discharges) were reported as number of cases (N) and percentages (%). Histograms, skewness, and kurtosis values were used to assess the normality of the data. As normality was met for CCI, in conjunction with the large sample size, parametric tests were used to assess the data variable across time [9]. Primary analyses pertaining to the outcomes focused on the effect of time for readmissions, complications, home discharges, and LOS between procedure types (ie, revision total knee arthroplasty [RTKA], revision total hip arthroplasty [RTHA]). Differences between procedure types (ie, RTKA and RTHA) regardless of time were also assessed.

Differences in age, BMI, CCI, and LOS were evaluated using multivariate analysis of variance across each time point between procedure types. Additionally, post-hoc testing was performed using least significant difference adjustments. Lastly, chi-square tests were performed to assess readmissions, complication rates, and home discharges across time between procedure types. Statistical significance was set as $P \leq .05$.

Results

Patient demographics

A total of 858 RTJA patients met inclusion criteria and were included in the final analyses. Of those, 43.8% (N = 376) patients underwent RTKA, and 56.2% (N = 482) underwent RTHA. The mean overall age was 66.42 ± 10.78 years, with no significant differences identified between procedure types (F [1, 837] = 0.12, P = .73). However, a significant difference was identified for BMI between procedure types (F [1, 837] = 72.15, $P < .001$), with the RTKA group having an overall higher BMI (mean difference = 3.99) than the RTHA group. A significant difference was also identified in the CCI between procedure types (F [1, 837] = 14.68, $P < .01$), with the RTKA group having an overall higher CCI (mean difference = 0.44) than the RTHA group.

There was an overall increase in the number of procedures performed (2015 = 36, PY5 = 151), with the largest increase (15%) occurring between PY1 and PY2 (Table 1). Additionally, the mean age of 66.43 ± 10.79 years remained similar over the participation period (F [5837] = 1.79, P = .11). Mean BMI for patients was 31.89 ± 6.71 and also remained similar over the participation period (F [5837] = 0.75, P = .59). However, the mean CCI changed over the participation periods from 3.91 ± 1.92 to 4.65 ± 2.14 (F [5, 837] = 2.90, P = .01) (Fig. 1); a significant increase was identified between 2015 and PY5 (mean difference = 0.74; P = .044), PY1 and PY4 (mean difference = 0.52; P = .041), PY1 and PY5 (mean difference = 0.67; P = .013), PY2 to PY4 (mean difference = 0.44; P = .021), and PY2 to PY5 (mean difference = 0.59; P = .005).

Outcomes

Upon assessment of the outcomes (ie, LOS, complications, readmissions, discharge to home), the overall average LOS was 4.02 ± 3.42 days, with an average complication rate of 11.7%, an average rate of readmissions of 16.2%, and an average home discharge rate of 70.5%. Pertaining to LOS, no significant differences were identified across time between procedure types (F [5, 837] = 11.28; P = .53). However, there was a significant difference in LOS across time regardless of the group (F [5, 837] = 2.48, P = .03; Table 1); the mean LOS was 5.14 ± 3.00 days at baseline and overall decreased to 4.50 ± 4.60 days at PY5. This finding was also represented by a significant decrease in LOS between 2015 to PY1 (mean difference = −1.39 days; P = .04), 2015 to PY2 (mean difference = −1.68 days; P = .01), 2015 to PY3 (mean difference = −1.57 days; P = .01), and 2015 to PY4 (mean difference = −1.32; P = .04). However, this decrease was followed by a significant increase in LOS between PY3 and PY5 (mean difference = 0.88 days; P = .02; Fig. 2).

Table 1
Outcomes across time periods.

Characteristic	2015 (n = 36)	PY1 (n = 82)	PY2 (n = 211)	PY3 (n = 180)	PY4 (n = 198)	PY5 (n = 151)	*P*-value
Age, years (±SD)	66.32 (±10.73)	65.81 (±9.78)	65.19 (±11.29)	68.11 (±9.73)	65.61 (±11.40)	67.60 (±10.78)	.11[a]
BMI, mean (±SD)	32.54 (±6.59)	30.12 (±6.22)	31.91 (±6.62)	32.18 (±6.73)	31.79 (±6.38)	32.45 (±7.44)	.59[a]
CCI, mean (±SD)	3.91 (±1.93)	3.99 (±1.68)	4.07 (±1.85)	4.42 (±1.76)	4.51 (±2.13)	4.65 (±2.14)	**.01**[a]
Readmissions, (%)							.19[b]
TKA	2 (10.5)	3 (11.5)	11 (10.4)	14 (16.7)	12 (15.0)	14 (25.0)	
THA	3 (17.6)	6 (10.7)	16 (15.2)	17 (17.7)	30 (25.4)	11 (12.2)	
Overall	5 (13.9)	9 (11.0)	27 (12.8)	31 (17.2)	42 (21.2)	25 (16.6)	
Complications, (%)							**.02**[b]
TKA	1 (5.3)	0 (0.0)	6 (5.7)	8 (9.5)	12 (15.0)	11 (18.0)	
THA	2 (11.8)	2 (3.6)	14 (13.3)	13 (13.5)	19 (16.1)	12 (13.3)	
Overall	3 (8.3)	2 (2.4)	20 (9.5)	21 (11.7)	31 (15.7)	23 (15.2)	
Home discharges, (%)							.26[b]
TKA	12 (63.2)	20 (76.9)	84 (79.2)	69 (82.1)	26 (67.5)	48 (78.7)	
THA	8 (47.1)	43 (76.8)	68 (64.8)	61 (63.5)	81 (68.6)	57 (63.3)	
Overall	20 (55.6)	63 (76.8)	152 (72.0)	130 (72.2)	135 (68.2)	105 (69.5)	
LOS, mean (SD, N)							.53[a]
TKA	5.21 (3.22, 19)	2.92 (1.77, 26)	2.98 (2.39, 106)	3.10 (2.16, 84)	3.75 (3.69, 80)	3.61 (3.28, 61)	
THA	5.06 (2.90, 17)	4.34 (3.71, 56)	4.31 (3.49, 105)	4.32 (2.98, 96)	4.18 (3.79, 118)	5.12 (5.21, 90)	
Overall	5.14 (3.00, 36)	3.90 (3.30, 82)	3.60 (3.10, 211)	3.80 (2.70, 180)	4.00 (3.40, 198)	4.50 (4.60, 151)	

Bolded = statistically significant.
SD, standard deviation; TKA, total knee arthroplasty; THA, total hip arthroplasty.
[a] Multivariate analysis of variance test statistic.
[b] Chi-square test statistic.

In addition, a significant difference was identified across time between procedure types for complications ($\chi^2 = 13.08$, $P = .01$; Table 1); the RTHA group had a higher complication rate (ie, 2015 = 11.8%, PY5 = 13.3%) compared to the RTKA group (ie, 2015 = 5.3%, PY5 = 8.0%). Patients discharged to home increased from 55.6% (2015) to 69.5% (PY5), however, no significant differences were identified across time between procedure types ($\chi^2 = 6.52$, $P = .26$). Additionally, the rate of readmission increased from 13.9% in 2015 to 16.6% at PY5, though this finding was not significantly different across time between procedure types ($\chi^2 = 7.41$, $P = .19$).

When comparing between procedure types, there were no significant differences identified for readmissions (mean = 16.2%; $\chi^2 = 0.84$, $P = .36$). This finding was also mirrored for complications (mean = 11.7%; $\chi^2 = 1.56$, $P = .21$). However, the LOS was significantly different between procedure types ($F[1, 837] = 1.64$, $P = .20$; Table 2), with the RTKA group having an overall lower LOS (2.63 days) compared to the RTHA group (3.86 days). In addition, there was a significant difference in the number of patients discharged home when comparing procedure types ($\chi^2 = 10.89$, $P \leq .01$). Upon further assessment, more patients in the RTHA group were discharged to home (52.6%, N = 318) compared to the RTKA group (47.4%, N = 287).

Discussion

Centers for Medicare and Medicaid Services has aimed to promote a value-based purchasing approach to both control costs and improve outcomes for TJA patients through the CJR program. Previous studies have demonstrated the success of bundled-payment models in patients undergoing a primary total hip arthroplasty and total knee arthroplasty with respect to cost-saving as well as preservation or improvement of key quality metrics [8,10]. However, an early concern with these programs was the possibility of unintended patient selection pressure, raising the possibility of patient "cherry picking" (ie, avoiding care for high-risk patients) [11,12]. Extended participation in these value programs may have altered care patterns even subtly over time, leading to selection-biased care of complex patients in safety-net hospitals. Thus, there is an inadequate understanding of the impact of prolonged participation in bundled-payment models on the "bundle-

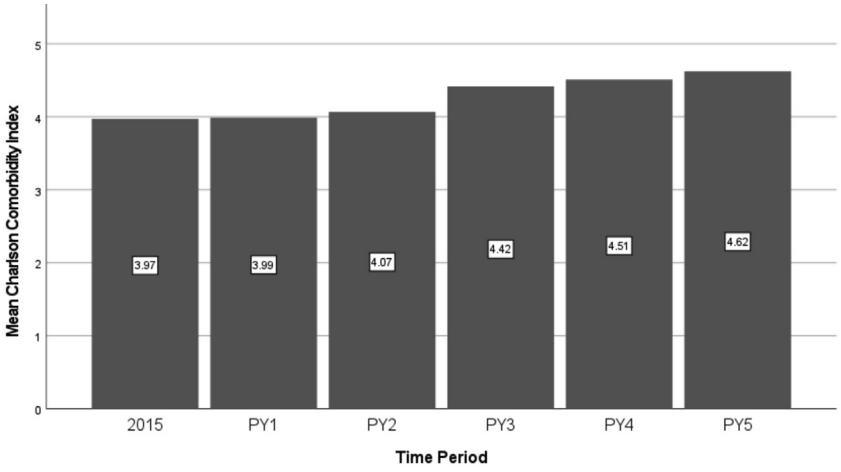

Figure 1. Overall mean of the Charlson comorbidity index across time periods.

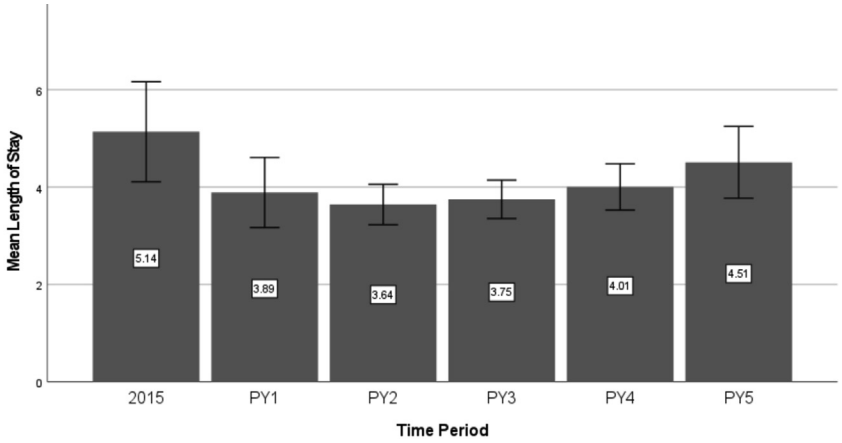

Figure 2. Overall mean length of stay across time periods.

adjacent" patients, who are also subject to regional selection pressure. This impact is especially acute in revision patients, who inherently consume increased resources due to their broader procedural and diagnostic variation, higher risk of complications, and operational difficulty.

Despite these concerns, previously published work showed a positive effect on all quality metrics in RTJA patients, even without a focused revision care pathway at the time [8]. Early positive results (ie, improvements in cost, readmissions, and disposition) were attributed to a halo effect from alterations in institutional practices toward all TJA patients with CJR implementation looming. During our prolonged participation in the CJR program over 5 years, however, we became aware that the medical complexity of our TJA patients was increasing, suggesting the need for alterations in care patterns. This experience led us to re-evaluate the CJR's long-term impact on our revision patients to investigate the extent to which the halo effect persisted.

Contrary to our initial hypothesis that RTJA patients would benefit from a bundled payment model as they had previously (ie, a "halo effect"), our RTJA patients surprisingly did worse in several key quality metrics (ie, the "horn effect," representing an associated negative impact from an intended quality improvement). The all-cause complication rate significantly increased over time from 8.3% to 15.2% ($P = .02$). This rate, though higher than our initial rate [8], is in line with similar studies[13-15]. Hasenauer et al. retrospectively evaluated 484 aseptic TJA revision patients for a 90-day follow-up [13]. They noted that major complications were reported in 34.9% of RTJA patients; in addition, significantly more complications existed in RTHA (42.6%) compared to RTKA (29.4%) ($P = .03$) [13]. Further, Nichols et al. reported that RTJA patients (ie, N = 43,288) over a 5-year period (ie, 2009-2013) that included a 90-day follow-up had an all-cause complication rate of 37.2% and 35% for RTKA and RTHA, respectively [14]. Moreover, Koenig et al. retrospectively assessed 306 RTHA patients from 2001-2009 and identified a complication rate of 34% in patients over 80 and 19% in patients 65-79 years old at 90-day follow-up [15].

Within our RTJA patients, there was also an increase in readmission rates from 13.6% to 16.6%; however, this finding was not statistically significant ($P = .19$). Similarly, Courtney et al. reported that of their RTJA patients (ie, N = 217) between 2013 and 2015, there was a 13% readmission rate within the 90-day follow-up [7]. Similarly, Hasenauer et al. also reported a 13% RTJA readmission rate and a 9.7% RTJA reoperation rate [13]. Lastly, Nichols et al. reported a readmission rate ranging from 21.7%-23.1% in RTKA and RTHA patients within 90 days [14]. However, given the variability within RTJA patients, a dramatic range in readmission rates is likely within the first 90 days [16-18].

The impact of CJR-induced shunting of arthroplasty patients and the resultant influx of more complex revision patients to tertiary-safety net hospitals on patient outcomes remains poorly characterized [5,19]. Previous literature has demonstrated challenges in managing these patients through both traditional fee-for-service and bundled-payment arrangements, with a consistent reduction in annual Medicare reimbursements despite increasing costs and volumes [20-23]. Rizk et al. noted an annual increase of 10.7% in revision volume from 2014-2019 in the Medicare population, with nearly 170,808 RTJA cases billed to CMS over that time period [23]; within our institution over the same time point, we observed a 42% increase in RTJA case volume, likely due in part to increased shunting of revision patients to our center.

Moreover, our patients became notably sicker on admission throughout the study period, with CCI increasing from 3.91 to 4.65 ($P = .01$) over time, in line with, though slightly higher than, prior reports from peer groups [7,13,14,24]. In addition, patients mean age and BMI in our study were 66.43 years and 31.89, respectively, which were similar in range to other studies

Table 2
Outcomes by procedure type.

Result	RTKA (n = 376)	RTHA (n = 482)	Overall (n = 858)	*P*-value
90-d readmissions, %	56 (14.9)	83 (17.2)	139 (16.2)	.36[a]
Complications, %	38 (10.1)	62 (12.9)	100 (11.7)	.21[a]
Home discharges, %	287 (76.3)	318 (66.0)	605 (70.5)	<.01[a]
LOS, mean (SD)	3.39 (2.63)	4.51 (3.86)	4.02 (3.42)	<.01[b]

SD, standard deviation.
[a] Chi-square statistic.
[b] Analysis of variance statistic.

identified [7,13]. Although patients were becoming more medically complex, the overall mean LOS decreased by 0.7 days over time. However, given that bundled payment programs penalize institutions for admissions to rehabilitation centers, the program at our institution preferred to keep patients in-house if it could facilitate home discharge. In addition, though the care pathway improvements were sufficient to allow for increased volume and management of more medically complex patients in a more resource-efficient manner, our institution could not parallel the same reductions in readmissions and complication rates that were able to be shown in the primary population. Though CJR does not presently account for revision cases, as the scope of these value-based arrangements increases over time, policies will be needed to protect hospitals and practices that function in a safety-net manner.

Given the projected increase in RTJA patients in the coming years and the reduction in Medicare hospital reimbursement for each RTJA procedure, it is valuable to address any disincentivizing of care for complex patients, including revision patients, due to concerns of reduced reimbursement from CJR or other value-based arrangements [23,25]. The current CJR program's emphasis on performance metrics such as complication rates, readmission rates, LOS, and patient-reported outcomes may not be as appropriate for complex RTJA patients and will require adjustments for the trends and complexity of RTJA cases [26-29]. Our 5-year study has demonstrated that the complexities and risks of revision care have superseded the previously described halo effect of a strong institutional practice characterized by 5 tenets: multidisciplinary oversight over the episode, improved optimization and stratification, preoperative education, early mobility and recovery, and discharge planning postdischarge tracking [8].

Limitations

This study does include limitations that warrant discussion. As with all retrospective studies, there may be unaccounted selection biases present that influence the results; however, as all data were obtained from the EMR and the population was all noninfected consecutive revision patients, we limited the likelihood of misreporting the outcomes and complication data for the patients included. The EMR also allowed us to consistently characterize the patients and their medical risks over the course of the study. Second, the reduction in cases observed during time period 5 is likely attributed to the COVID-19 pandemic, which may have impacted some of the outcomes through a unique selection pressure during that time period. Although the pandemic likely reduced our sample size and impacted the trends seen, the given trends in the prior time periods accurately display the increase in revision cases over time. Lastly, due to the data being pooled and blinded, we were unable to assess sex and other demographic characteristics (eg, Risk Assessment and Prediction Tool) in relation to specific complications or readmissions. In addition, due to the blinded nature of the data pull, referral sources of these patients are unable to be determined. Other studies have demonstrated that this pattern exists under the CJR program [30]. A better understanding of regional referral patterns associated with CJR is important to improve value-based care models.

Conclusions

Despite a demonstrably efficient, safe, high-value care pathway for arthroplasty patients that was iteratively improved over 5 years of CJR participation, quality metric improvements in revision arthroplasty failed to show "stickiness" and instead displayed a "horn effect" of increasing medical complexity during the participation period. The RTJA patients in our data demonstrated a higher readmission and complication rate despite our efforts to improve value across the whole pathway and promising early results. These findings may be attributable to a significantly higher burden of disease over time as well as higher patient and technical complexity. Also, our findings display the need to further investigate the impact of mandatory bundled payment programs like CJR on the care of primary and RTJA patients regionally and nationally and emphasize the importance of risk adjustment in monitoring performance outcomes associated with arthroplasty care.

Conflicts of interest

H. K. Parvataneni is an editorial board member of JOA, Arthroplasty Today, and Operative Techniques in Orthopaedics and is a member of the Florida Orthopaedic Society Program Committee and the AAHKS Fellowship Match and Oversight Committees. C. F. Gray is a paid consultant for Smith & Nephew and Adler Orthopaedics, has stock options in DeBogy Molecular, and is a committee member of the American Academy of Orthopaedic Surgeons. H. A. Prieto is a paid consultant for Smith & Nephew Inc.; receives research support from Zimmer Biomet Inc. and Smith & Nephew Inc.; is a reviewer of the Journal of Arthroplasty, Arthroplasty Today, and The Journal of Knee Surgery; and is a chair program committee member of the Florida Orthopaedic Society. All other authors declare no potential conflicts of interest.

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CRediT authorship contribution statement

Akshay Reddy: Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Emilie N. Miley:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Hari K. Parvataneni:** Writing – review & editing, Writing – original draft, Conceptualization. **Hernan A. Prieto:** Writing – review & editing, Writing – original draft, Conceptualization. **Chancellor F. Gray:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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