Journal of Medical Economics

ISSN: 1369-6998 (Print) 1941-837X (Online) Journal homepage: www.tandfonline.com/journals/ijme20

Economic and clinical value of hydrolyzed collagen in the management of spine surgery wounds: a cost-effectiveness analysis

Vivek Mohan, Joshua E. Meyers, Benjamin G. Cohen, Paul Steel & William V. Padula

To cite this article: Vivek Mohan, Joshua E. Meyers, Benjamin G. Cohen, Paul Steel & William V. Padula (2026) Economic and clinical value of hydrolyzed collagen in the management of spine surgery wounds: a cost-effectiveness analysis, Journal of Medical Economics, 29:1, 772-784, DOI: 10.1080/13696998.2026.2639234

To link to this article: https://doi.org/10.1080/13696998.2026.2639234

JOURNAL OF MEDICAL ECONOMICS
2026, VOL. 29, NO. 1, 772–784
https://doi.org/10.1080/13696998.2026.2639234
Article /2639234

Taylor & Francis
Taylor & Francis Group

ORIGINAL RESEARCH

Economic and clinical value of hydrolyzed collagen in the management of spine surgery wounds: a cost-effectiveness analysis

Vivek Mohan[a], Joshua E. Meyers[b,c], Benjamin G. Cohen[d], Paul Steel[d] and William V. Padula[d,e,f]

[a]Orthopaedic Spine Institute, Schaumberg, IL, USA; [b]Department of Neurosurgery, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, New York, NY, USA; [c]Department of Neurosurgery, Buffalo General Medical Center, Kaleida Health, Buffalo, NY, USA; [d]Stage Analytics, Suwanee, GA, USA; [e]Department of Pharmaceutical & Health Economics, Mann School of Pharmacy & Pharmaceutical Sciences, University of Southern California, Los Angeles, CA, USA; [f]The Leonard D. Schaeffer Center for Health Policy & Economics, University of Southern California, Los Angeles, CA, USA

ABSTRACT

Aims: To assess the cost-effectiveness of hydrolyzed collagen as an adjunct to standard care for reducing postoperative complications in high-risk spinal surgery patients.

Methods: A decision tree model was developed from the U.S. healthcare sector perspective to compare hydrolyzed collagen with standard care alone over a one-year time horizon. The model followed a cohort of high-comorbidity patients undergoing complex spinal procedures, capturing postoperative infections, seromas, hematomas, readmissions, and revision surgeries. Clinical inputs were derived from published evidence, and costs were reported in 2025 U.S. dollars. Outcomes included direct medical costs, QALYs, and net monetary benefit (NMB) at a willingness-to-pay threshold of $100,000/QALY. Univariate, probabilistic, and threshold sensitivity analyses assessed parameter uncertainty.

Results: Hydrolyzed collagen dominated no treatment, generating $3,853 in cost savings and a 0.007 QALY gain per patient over one year, yielding an NMB of $4,542. Avoided readmissions and revision procedures were the primary contributors to cost savings. Baseline complication rates, relative risk reduction, and complication persistence rates were the most influential parameters. In probabilistic analysis, hydrolyzed collagen was cost-effective in more than 99% of simulations.

Limitations: The analysis applies simplifying assumptions, a one-year time horizon, and heterogeneous clinical inputs, factors that may limit the generalizability of the findings.

Conclusions: Compared to standard care alone, hydrolyzed collagen demonstrated a dominant strategy associated with cost savings and improved health outcomes for high-risk spinal surgery patients. These findings support its consideration as a value-enhancing component of the spine surgery care pathway, particularly for patients with elevated complication risk.

PLAIN LANGUAGE SUMMARY

Complications after spine surgery, such as infections, fluid collections, and wound breakdown, are common in high-risk patients and drive substantial clinical and economic burden through unplanned readmissions, prolonged recovery, and revision procedures. In this study, a decision tree model was developed from the US healthcare sector perspective to estimate the clinical and economic impact of adding a topical hydrolyzed collagen powder to the existing spine surgery bundle for high-comorbidity patients undergoing complex spinal procedures. The model compared standard care alone with standard care plus hydrolyzed collagen over one year, capturing complications, their resolution or persistence, and downstream events such as readmissions and revision surgeries, while assigning costs in 2025 US dollars and quality-adjusted life years (QALYs) to each pathway. The analysis found that adding hydrolyzed collagen dominated no treatment, improving outcomes and reducing costs: per patient, the intervention generated an additional 0.007 QALYs and saved approximately

ARTICLE HISTORY

Received 24 December 2025
Revised 17 February 2026
Accepted 26 February 2026

KEYWORDS

Spine surgery; wound management; adjunctive therapies; cost effectiveness; hydrolyzed collagen

JEL CODES

I00; I10

CONTACT William V. Padula padula@usc.edu Department of Pharmaceutical and Health Economics, USC Schaeffer Center, 635 Downey Way (VPD), Los Angeles, CA 90089, USA

Supplemental data for this article is available online at https://doi.org/10.1080/13696998.2026.2639234.

www.tandfonline.com/ijme

$3,852, yielding a net monetary benefit of $4,542 at a $100,000/QALY willingness-to-pay threshold. Avoided readmissions accounted for 58% of cost savings and avoided revision surgeries for an additional 22%, underscoring the economic impact of preventing serious complications. Threshold and sensitivity analyses showed a wide margin for maintaining value, with hydrolyzed collagen remaining cost-effective across plausible ranges of baseline complication risks, treatment effects, and product costs. The findings suggest that integrating hydrolyzed collagen into spine surgery wound management can meaningfully reduce complications and overall costs, supporting its use as a cost-effective adjunct in high-risk spinal surgery care.

Introduction

Background – spine surgeries and complications

Spine surgeries are widely performed in the United States (US), with over one million procedures conducted annually, to treat various degenerative, traumatic, and structural conditions[1,2]. These procedures aim to reduce back pain, restore mobility, and improve function. However, concerns persist regarding postoperative complications, such as infections, and other potential risks to patients that can delay recovery and necessitate revision procedures[3]. The presence of comorbidities further elevates the risk of complications, particularly for patients undergoing complex and invasive surgeries[4,5]. Common postoperative issues include surgical site infections (SSI), hematomas, seromas, and dehiscence, all of which can compromise healing and patient outcomes.

Chronic or severe complications may result in costly, unplanned readmissions or surgical revisions, key metrics for hospital performance, reflecting both care quality and postoperative morbidity burden[6]. Surgical revisions caused by non-healing and infected wounds vary by severity and depth and are generally required when the infection involves the implant surface[7,8]. Moreover, complications after spine surgery substantially increase healthcare resource utilization, including: emergency department visits, advanced imaging, opioid prescriptions, and referrals for pain management or rehabilitation services[9,10]. The financial and operational strain of SSIs is particularly well documented, often involving extended lengths of stay (LOS), prolonged antibiotic use, and additional interventions[11–13]. Given these multifaceted impacts, implementing preventive strategies to reduce the incidence of post-operative complications may offer multilevel benefits for both hospital systems and patients by improving outcomes, reducing resource utilization, and mitigating long-term costs.

Intervention and study objective

A variety of interventions are employed to reduce the risk of SSIs, which may be implemented at different points in the care continuum – before, during, or after surgery[14]. In spine surgery specifically, intraoperative adjuncts play a critical role, as even minor complications can significantly impact patient recovery and lead to increased healthcare resource utilization. Evidence has demonstrated that such adjuncts, like vancomycin, can reduce SSIs and related complications, yielding both clinical and economic benefits[15,16].

Type I bovine hydrolyzed collagen is a topical adjunct with unique peptide sequences and properties[17,18]. Designed to modulate the wound environment, the powder promotes hemostasis through platelet activation and aggregation, supports immunomodulation, facilitates proliferation *via* signaling pathways, and aids in tissue remodeling. The surgical powder is used in a variety of specialties, with studies conducted across elective[19], orthopedic[20], and neurosurgical procedures[21–24].

Hydrolyzed collagen supports wound healing and helps reduce the risk of postoperative complications such as dehiscence. In a case series of 54 consecutive patients undergoing spinal surgery for deformity correction or fracture, Gitelman et al. reported no SSIs or wound dehiscence between two and six weeks postoperatively[21]. Dickerman et al. observed no wound complications in a prospective study of 102 neurosurgical patients when hydrolyzed collagen was used alongside vancomycin[22]. Similarly, a retrospective review by Hotchkiss in 154 spinal surgery patients reported a low complication rate (1.9%), limited to three high-risk individuals, all of whom were managed conservatively without readmission[23].

Earlier reviews highlight a growing emphasis on cost-effectiveness analyses (CEAs) in spinal surgery to evaluate both procedural and perioperative strategies, with outcomes varying based on patient risk profiles and complication rates[25,26]. In the context of value-based care, where outcomes and cost-efficiency are increasingly prioritized, preventive strategies to reduce hospital-acquired injuries offer meaningful economic savings[27,28]. Here, we analyze the cost-effectiveness of hydrolyzed collagen as part of the spine surgery bundle (e.g. preoperative skin and nasal decolonization, timely antibiotic prophylaxis, alcohol-based antiseptic skin preparation, sterile technique, normothermia maintenance, and appropriate wound care) where hydrolyzed collagen supports a favorable wound environment conducive for the body's own wound healing process. Clinicians sometimes add vancomycin powder and negative pressure dressings due to higher infection risk associated with instrumentation and multilevel procedures. The bundle, modified only by the addition of hydrolyzed collagen, may contribute to preventing complications in acute surgical wounds.

Methods

CEA study design

A decision tree was developed from the US healthcare perspective to analyze the cost-effectiveness of hydrolyzed collagen (CellerateRX® Surgical Powder; Sanara MedTech, Fort Worth, TX) as an adjunct to spinal surgery, compared to the standard of care without hydrolyzed collagen ("No Treatment"). The model followed a cohort of patients with a high likelihood of complications (e.g. high-comorbidity patients) undergoing complex spinal procedures, which is reflected in the baseline complication risk. This high-risk population was chosen to reflect a clinically relevant group in which adjunctive wound interventions like hydrolyzed collagen may offer the greatest benefit by supporting wound management.

A one-year time horizon was used to estimate both clinical outcomes and direct medical costs. This period was selected to capture clinically and economically meaningful postoperative outcomes such as surgical success, wound healing, and the incidence of complications, readmissions, and revision procedures. Importantly, it represents the window during which hydrolyzed collagen is expected to provide its greatest benefit and encompasses hospital accountability for postoperative readmissions, particularly within the first 30 days, when financial penalties are most directly applied[6]. The horizon was intentionally chosen to avoid overstating potential economic or quality of life (QoL) effects beyond the period in which its mechanism of action is relevant.

As such, longer-term differences beyond one year were not modeled, as functional recovery and resolution of wound-related sequelae generally occur during the post-operative recovery period, even for more invasive spinal procedures. Once wound healing is complete, patients are expected to transition to similar long-term trajectories irrespective of initial wound management.

Patients were subsequently categorized into non-complicated (i.e. successful surgeries) and complicated cases to enable a comparative analysis of cost and quality-of-life (QoL) impacts. Clinical effectiveness was measured in units of quality-adjusted life years (QALYs), enabling comparison between interventions in terms of QoL. Cost estimates were adjusted to 2025 US Dollars (USD) to account for data reported in earlier years. As the time horizon was limited to one year, discounting of costs and outcomes was not applied.

The primary outcome of the analysis was the incremental cost-effectiveness ratio (ICER), defined as the difference in costs divided by the difference in QALYs between treatment arms. To complement the ICER, net monetary benefit (NMB) was also calculated. This metric translates health gains into monetary terms based on a prespecified willingness-to-pay (WTP) threshold. A $100,000 USD/QALY WTP threshold was used to assess the cost-effectiveness of hydrolyzed collagen. All modeling and analyses were conducted in 2025 using Microsoft Excel (Microsoft Inc., US).

Model structure

The model begins at the decision node, where high-comorbidity patients undergoing complex spinal surgeries with hydrolyzed collagen or No Treatment for management of their acute surgical wounds;

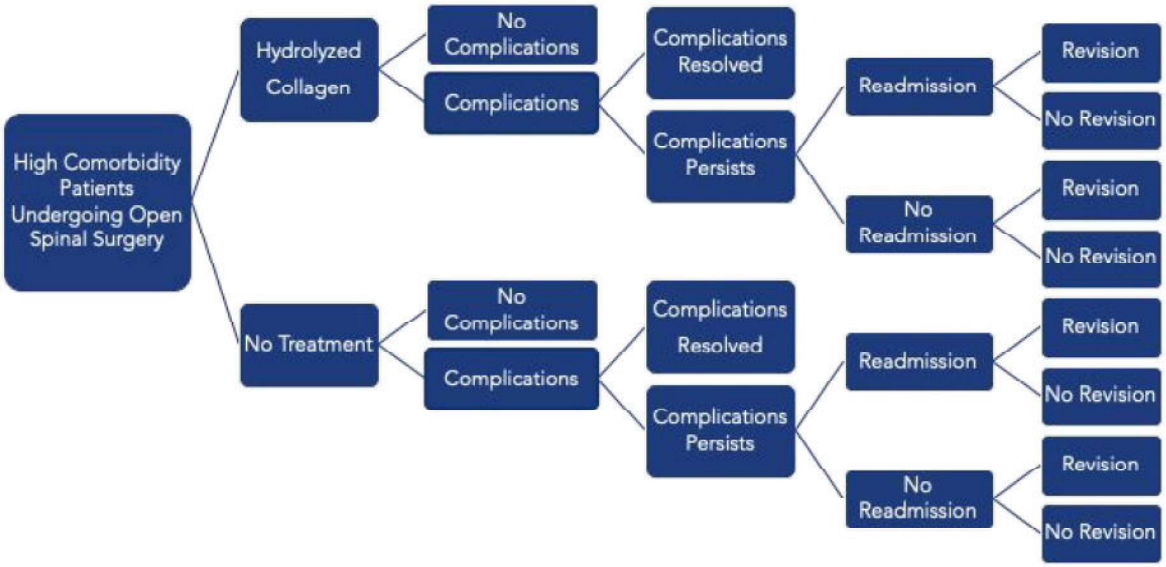

Figure 1. Decision tree diagram.
Key Health States:
Complications: Patients experiencing complications include infections, seromas, hematomas, and dehiscence; infections were managed with either oral antibiotics in the outpatient setting or with a combination of IV and oral antibiotics following inpatient or outpatient wound revision. Revision: Surgical revisions include wound revisions of varying severity and, in some cases, implant revisions alongside or after wound revision. Death: Transitions to death were possible from any health state in the model.
Assumption: Wound revisions can occur outside of a hospital admission.

index surgery costs were excluded from the cost estimates (Figure 1). Following surgery, patients transition into one of two health states: experiencing complications ("Complications") or not ("No Complications"). The No Complications state represents a successful surgery with no additional costs or QALY decrements. For those who do experience complications, outcomes diverge further – some resolve ("Complications Resolved") with standard management (e.g. oral antibiotics) or persist and become chronic ("Complications Persist"), potentially requiring hospital readmission and/or surgical revision. The model assumed wound revisions could occur with or without hospital admission. Additionally, a retrospective review informed the baseline probability of post-surgical mortality[29], which varied by health state and increased with the severity and persistence of complications.

Downstream events following complications were modeled conditionally and sequentially. Specifically, persistence of complications, readmission, and revision were applied as dependent events alongside a single pathway, such that each patient could occupy only one mutually exclusive sequence of outcomes. Revision procedures were modeled as occurring within the readmission pathway and were not counted independently in patients who did not experience readmission, thereby preventing double counting of events and associated costs.

Clinical inputs and transition probabilities

Published literature informed transition probabilities at each branch of the decision tree (Table 1). A synthesis of clinical studies established the baseline post-surgical complication rate, incorporating events such as infections, hematomas, seromas, and wound dehiscence[19–24,30]. The modeled surgical case mix reflected real-world clinical practice and included procedures such as open spine surgeries, spinal fusions, laminectomies, discectomies, foraminotomies, spinal decompression, vertebroplasty, osteotomy, and kyphoplasty. These same studies also helped develop a baseline estimate for the clinical efficacy of the spine surgery bundle in reducing the risk of post-surgical complications. This evidence-based approach accounted for variability in both complication rates and intervention effectiveness across diverse clinical settings.

Table 1. Model parameters.

Parameter	Base case	Lower bound	Upper bound	Distribution	References
Clinical					
No Treatment					
No Complication Rate	89.68%	–	–	–	Calculation
Post-Surgical Complication Rate	10.00%	5.66%	15.40%	Beta	[19–24,30]
Post-Surgical Mortality Rate	0.32%	0.19%	0.50%	Beta	[29]
Hydrolyzed Collagen					
No Complication Rate	96.68%	–	–	–	Calculation
Post-Surgical Complication Rate	3.00%	–	–	–	Calculation
Post-Surgical Mortality Rate	0.32%	0.19%	0.50%	Beta	[29]
Relative Risk Reduction	70.00%	31.26%	96.23%	Beta	[19–24]
Treatment Independent					
Mortality Rate		Variable across health states (e.g. following complication or readmission)			
Complication Persistence Rate	60.69%	29.65%	87.43%	Beta	[30]
Total Readmission Rate	41.23%	–	–	–	Calculation
30-Day Readmission Rate	25.08%	13.88%	38.29%	Beta	[31]
60-Day Readmission Rate	13.27%	7.47%	20.40%	Beta	[31]
90-Day Readmission Rate	7.96%	4.51%	12.26%	Beta	[31]
Revision After Readmission Rate	41.23%	22.01%	61.97%	Beta	[31]
Revision Rate w/out Readmission	22.44%	12.48%	34.33%	Beta	[31]
Costs					
No Complication					
Total Cost	$2,613	–	–	–	Calculation
Medication	$170	$155	$100	Gamma	[32]
Lab Tests	$171	$170	$142	Gamma	[32]
Imaging	$1,192	$1,244	$776	Gamma	[32]
Therapy	$1,081	$1,094	$1,014	Gamma	[32]
Complications					
Total Cost	$7,516	–	–	–	Calculation
Medication	$2,244	$1,285	$3,466	Gamma	[32]
Lab Tests	$848	$697	$1,015	Gamma	[32]
Imaging	$2,467	$1,699	$3,375	Gamma	[32]
Therapy	$1,597	$1,216	$2,029	Gamma	[32]
Complications Resolved					
Added Cost to Index Procedure	$10,069	$6,910	$13,812	Gamma	[32]
Complications Persist					
Minor SSI Treatment Cost	$22,566	$21,493	$23,666	Gamma	[12]
Deep SSI Treatment Cost	$31,147	$29,306	$33,044	Gamma	[12]
Readmission					
Added Cost to Index Procedure	$113,776	$110,905	$116,684	Gamma	[33]
Revision					
Added Cost to Index Procedure	$63,517	$61,637	$65,426	Gamma	[34]
Utilities					
Pre-Operative Period (Utility)	0.4097	0.4081	0.4114	Beta	[35]
Post-Operative Period (Utility)	0.7226	0.7218	0.7234	Beta	[35]
No Complications (Utility)	0.7520	0.7510	0.7530	Beta	[35]
Complications (Disutility)	0.1500	0.1218	0.1805	Beta	[32]
Persistent Complications (Utility)	0.6020	–	–	–	Calculation
Readmission (Utility)	0.4097	–	–	–	Assumption
Revision (Utility)	0.4097	–	–	–	Assumption

Abbreviation. SSI, surgical site infection.

Additionally, clinical analyses informed the probability of complication persistence[30], as well as the likelihood of subsequent hospital readmission and revision surgery[31]. Readmissions and revisions were treated as consequences directly linked to postsurgical wound complications. While the referenced treatment arm studies primarily report on complication rates, such as SSIs, the model extrapolated these events to capture their broader clinical and economic impact, even in the absence of direct trial data on longer-term outcomes. Notably, the downstream consequences of complications were modeled identically across both treatment arms, as hydrolyzed collagen, as an adjunct, was not expected to impact readmission or revision rates once a complication occurred.

Costs

The model assigned costs to each health state over the one-year time horizon, using data from published literature and reflecting the expected duration of health state occupancy by treatment arm (Table 1). Estimates for immediate postoperative health states were derived by comparing the costs incurred by

patients with and without infections following spine surgery procedures, including expenses related to laboratory tests, medications, imaging, and therapy[32]. Additional analyses informed the costs associated with downstream events such as chronic complications, hospital readmissions, and revision surgeries[12,33,34]. We assumed a base-case hydrolyzed collagen acquisition cost of $1,000, applied exclusively to the treatment arm, recognizing that pricing may vary by patient and care setting. while costs associated with the index spinal operation were excluded from the analysis to isolate the economic impact of the bundle. All cost inputs were standardized to 2025 U.S. dollars using a 3% annual inflation rate.

Health utility

Health utility weights were applied to each health state based on the amount of time individuals were expected to occupy that state. These utilities, which range from 0 (representing death) to 1 (representing perfect health), were used to calculate QALYs over the one-year time horizon. Each model health state was assigned a utility value, which was aggregated to estimate total QALYs across both treatment arms (Table 1).

Utility inputs were derived from published literature, with assumptions and additional calculations used for downstream health states as needed. A systematic literature review and meta-analysis provided pre- and post-operative QoL scores for degenerative cervical and lumbar diagnoses[35]. To capture the impact of complications, the disutility associated with postoperative infection[32] was subtracted from the No Complications state to calculate the utility for the Persistent Complications state. As expected, patients who experienced no complications or had early resolution received the highest utility scores, while those experiencing persistent complications, readmissions, or revisions had the lowest utility scores, reflecting greater morbidity and reduced QoL.

Time in state assumptions were designed to reflect the expected clinical course of postoperative recovery. A 30-day disutility was applied to reflect the acute postoperative period for patients experiencing complications, with an additional 30-day disutility (60 days total) applied for patients with persistent complications prior to resolution. For patients experiencing hospital readmission, utility was assumed to temporarily (30 days) revert to pre-operative QoL levels.

Sensitivity analyses

Sensitivity analyses were conducted to assess how changes in model inputs could influence the results. First, a threshold analysis was performed to identify breakeven values, defined as the point in which the NMB equals $0 USD, for three key inputs: (a) the baseline post-surgical complication rate, (b) the relative risk reduction associated with hydrolyzed collagen as an adjunct to wound management, and (c) the acquisition cost of hydrolyzed collagen. To further explore the impact of input uncertainty, both univariate and probabilistic sensitivity analyses (PSA) were conducted. In the univariate sensitivity analysis, each parameter was adjusted individually to its upper and lower bounds while all other variables were held constant. These bounds were based on reported standard errors (SE) when available, or an assumed ±25% SE around the point estimate when unavailable.

The PSA simultaneously and randomly varied all model inputs according to their point estimates, variability, and assigned statistical distributions, with 10,000 Monte Carlo simulations used to characterize overall model uncertainty and generate an ICER scatterplot. Parameters expressed as percentages or utility scores (ranging between 0 and 1) were modeled using a Beta distribution, while all other parameters with positive, non-zero values followed a Gamma distribution.

Lastly, 30- and 90-day time horizons were modeled as scenarios to reflect short-term outcomes relevant to hospital systems, including early complication prevention and resource utilization. These scenarios do not capture longer-term sequelae or costs that occur beyond the modeled periods.

Assumptions

Several assumptions were needed for the economic model to structure the analysis and interpret results. It was assumed that the index surgery cost would be the same across both treatment arms and was

therefore excluded from the model; accordingly, reported costs represent incremental expenses beyond the initial procedure, including the acquisition cost of hydrolyzed collagen in the treatment arm.

The model population was assigned a uniform 10% baseline risk of postoperative complications to reflect a clinically relevant high-risk spine surgery cohort. This assumption represents patients undergoing more invasive, open spinal procedures – where complication risk is higher than in minimally invasive approaches – and those with other risk factors (e.g. obesity). Reported complication rates across spine surgery literature vary widely (e.g. 2-20%) depending on patient risk profile, procedure type, and use of adjunctive strategies; the 10% baseline was selected to represent an intermediate, conservative estimate within this range, consistent with populations in which hydrolyzed collagen is most utilized in practice[19–24,30]. The model also assumes a representative value of 70% relative risk reduction in postoperative complications associated with hydrolyzed collagen, based on studies with varying reported effects[19–24]. Studies informing this assumption, including the design, patient populations, outcomes assessed, follow-up duration, and use of co-interventions, are summarized in the Appendix (eTable 1).

Revisions were assumed to occur in both inpatient and outpatient settings; however, if revisions were delivered exclusively in inpatient settings, total costs would be higher than estimated. Additionally, the model assumed that patients who experienced complications would face equivalent downstream consequences, both in frequency and cost, regardless of treatment arm. If the treatment arm mitigates the severity or economic burden of complications after they occur, the model's results would underestimate its benefit, thereby representing a conservative or lower-bound estimate of its cost-effectiveness.

Results

CEA base case results

Hydrolyzed collagen dominated No Treatment over a one-year time horizon, providing both improved clinical outcomes and cost savings. Specifically, the treatment arm yielded an additional 0.007 QALYs and reduced costs by $3,852 per patient (Table 2). This indicates that hydrolyzed collagen, when used as an adjunct to wound management within the spine surgery bundle, contributed to greater health benefits to patients and the health system at a lower overall cost compared to No Treatment.

At a $100,000 WTP per QALY threshold, the base case NMB was $4,542. Scenarios lowering only the baseline complication rate to 8%, 5%, and 2% showed that hydrolyzed collagen remained cost-effective, with corresponding NMBs of $3,434, $1,771, and $108. Similar results were observed when reducing the treatment effect to 60%, 40%, and 20%, yielding NMBs of $3,750, $2,167, and $583, respectively.

A comparison of costs across health states in each treatment arm identified key cost drivers underlying the observed savings. Related to the spine surgery bundle, of the $3,852 in per patient savings, $2,238 (58%) come from avoiding readmissions, $835 (22%) from avoiding revisions, and the remainder (20%) from non-complicated surgeries and less unplanned resource use.

The threshold analysis calculated the independent breakeven values for the following parameters: a baseline post-surgical complication rate of 1.80%, a relative risk reduction of 12.63%, and an acquisition

Table 2. One-year cost-effectiveness results and savings breakdown.

Cost-Effectiveness Results (Per Patient)	
Cost of Spinal Procedure with Hydrolyzed Collagen	$5,684
Cost of Spinal Procedure with No Treatment	$9,537
Cost Savings for Hydrolyzed Collagen	$3,852
QALYs Associated with Hydrolyzed Collagen	0.747
QALYs Associated with No Treatment	0.740
QALY Gains for Hydrolyzed Collagen	0.007
ICER ($/QALY)	Dominant
NMB at $100,000 WTP Threshold	$4,542
Cost Savings Breakdown (Per Patient)	
Total Cost Savings for Hydrolyzed Collagen	$3,852
Hydrolyzed Collagen Cost Savings Attributable to Avoided Readmissions	$2,238
Hydrolyzed Collagen Cost Savings Attributable to Avoided Revisions	$835

Abbreviations. ICER, incremental cost-effectiveness ratio; NMB, net monetary benefit; QALY, quality-adjusted life year; WTP, willingness to pay.

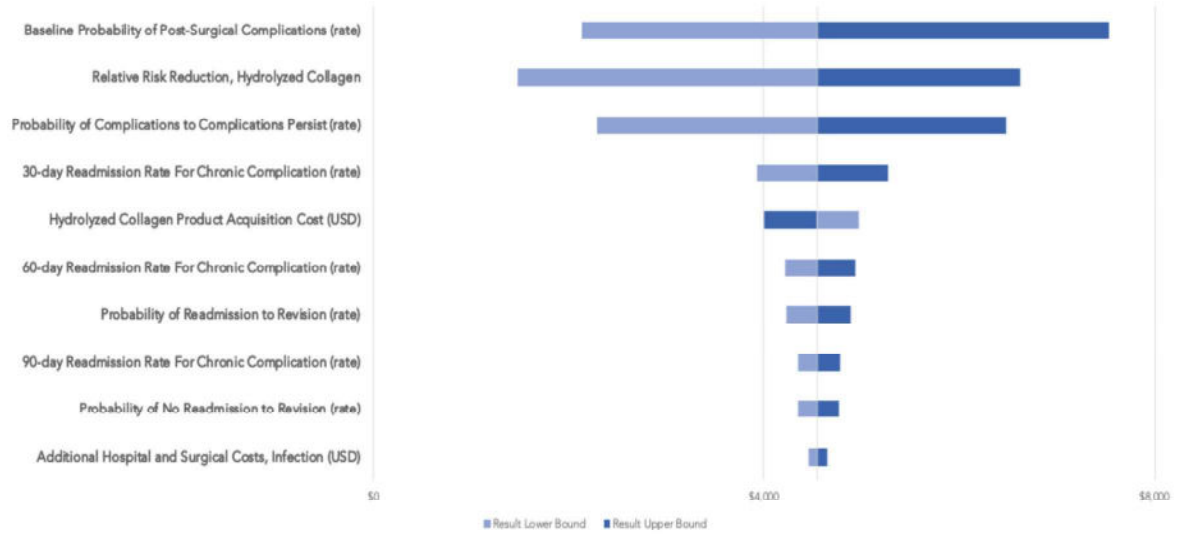

Figure 2. Tornado diagram: univariate sensitivity results. One-year NMB.
The threshold analysis identified the breakeven values (where the NMB = $0 USD) for the following parameters: Baseline Post-Surgical Complication Rate (1.80%), Hydrolyzed Collagen Relative Risk Reduction (12.63%) and Hydrolyzed Collagen Acquisition Cost ($5,542).
Abbreviations. NMB, net monetary benefit; USD, United States Dollar.

cost of $5,542 for hydrolyzed collagen. These values represent the conditions under which hydrolyzed collagen, as part of the spine surgery bundle, would no longer be considered cost-effective.

Sensitivity analyses

The univariate sensitivity analysis showed that hydrolyzed collagen remains cost-effective at a $100,000 WTP per QALY threshold in all scenarios (Figure 2). Over the one-year time horizon, the model was most sensitive to three key parameters: the baseline probability of post-surgical complications, the relative risk reduction associated with hydrolyzed collagen, as part of the spine surgery bundle, and the complication persistence rate. In the PSA, which accounted for simultaneous variation in all input parameters, hydrolyzed collagen was dominant in over 99% of scenarios (Figure 3).

Over a 30-day time horizon, hydrolyzed collagen also dominated No Treatment, yielding early clinical and economic benefits with an additional 0.001 QALYs and $445 in cost savings per patient, resulting in a NMB of $540. Over a 90-day time horizon, the intervention generated an additional 0.002 QALYs and $731 in cost savings, with an NMB of $967, reinforcing its value across multiple relevant care windows.

Discussion

This CEA found that hydrolyzed collagen is a dominant strategy compared to No Treatment in the management of spinal surgery wounds. From the perspective of the US healthcare sector, hydrolyzed collagen yielded both clinical and economic benefits, delivering an incremental gain of 0.007 QALYs and a cost savings of $3,852 per patient over a one-year time horizon. The cost-effectiveness of hydrolyzed collagen would be sustained at any WTP threshold, reinforcing its potential role in surgical wound management, particularly within high-risk or comorbid patient populations.

The model captures a range of clinical severities representative of real-world surgical care. While most patients underwent non-complicated procedures, a smaller subset experienced complications, readmissions, and revisions – events that disproportionately drove higher healthcare costs. By reducing the incidence of complications, hydrolyzed collagen indirectly lowered the likelihood of these resource-intensive events. This translated into meaningful savings, with avoided hospital readmissions accounting for 58% of total cost reductions and avoided revision surgeries contributing an additional 22%. These findings emphasize the clinical and economic importance of preventing complications early in the care pathway,

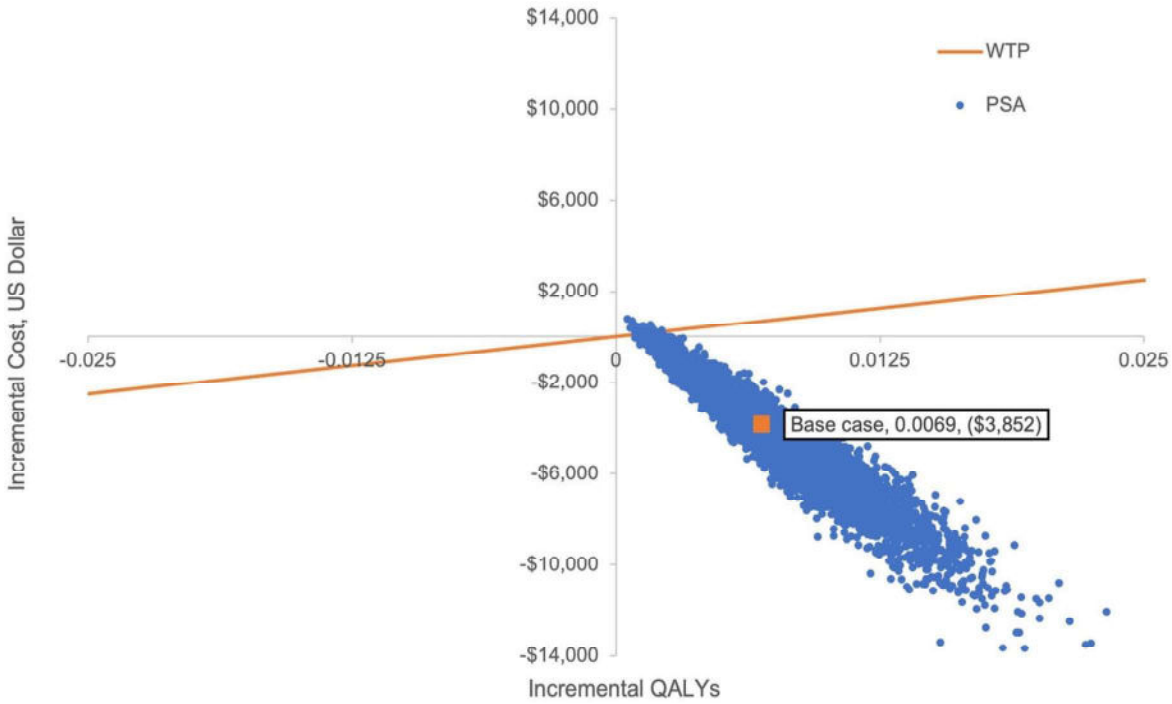

Figure 3. Probabilistic sensitivity analysis. Results: one-year scatterplot.

where targeted intervention, including wound management adjuncts, can meaningfully reduce avoidable utilization and improve patient outcomes.

The 30- and 90-day scenarios further highlight hydrolyzed collagen's value in the immediate postoperative period, where hospitals are especially sensitive to early complication and readmission rates. Even within these shorter windows, hydrolyzed collagen yielded measurable gains – an additional 0.001–0.002 QALYs and $445-$731 in savings per patient – reinforcing its relevance as a near-term cost saving intervention within hospital-managed care episodes. Clinical outcomes and economic consequences are tightly linked in surgical care. Preventing deleterious events like SSIs helps improve QoL and simultaneously reduces the need for high-cost interventions. In this model, the QALY gains, although modest, reflect differences in health states associated with the presence, persistence, and resolution of complications.

The model was calibrated using a 10% baseline complication rate and a 70% relative risk reduction for the treatment arm, reflecting averages derived from available literature. Reported SSI rates in the literature varied widely from as low as 2-4% to over 20%, offering directional evidence for elevated complication rates[19–24,30]. The clinical efficacy of the treatment arm was similarly drawn from a range of studies, including some reporting complete prevention of complications. Because no single study provided definitive values for either parameter, representative inputs for the model were derived by synthesizing estimates from multiple published sources.

The threshold analysis suggests a wide margin for maintaining value, making it likely that integrating hydrolyzed collagen into spinal surgical protocols, particularly for high-risk or comorbid patients, could be clinically and economically beneficial. In scenarios with extremely low complication rates, minimal product efficacy, or significantly increased acquisition costs would meaningfully diminish cost-effectiveness.

Model uncertainty was explored through sensitivity analyses, all of which supported the consistency of the findings. The univariate sensitivity analysis identified the baseline complication rate, relative risk reduction of treatment arm, and complication persistence rate as the most influential parameters. Even when these and other variables were varied across a credible range of clinical and economic inputs, hydrolyzed collagen, as part of the bundle, consistently remained cost-effective. The PSA further reinforced these results, with hydrolyzed collagen dominant in over 99% of simulated scenarios.

These findings align with prior evidence highlighting the substantial economic burden of SSIs[11] and related healthcare-associated infections (HAIs)[36], which continue to pose significant challenges to health systems in both clinical and financial terms. They also reinforce broader research showing that readmissions and revisions are key drivers of postoperative spending, often contributing to disproportionately expensive episodes of care[37,38]. In addition to direct costs, extended hospital stays generate opportunity costs for the healthcare system by occupying capacity that could otherwise serve new patients. For example, a study by Shepard et al. highlights that preventing a single HAI can enable hospitals to backfill the freed capacity with up to 4.62 new admissions, thereby increasing revenue and profit[36]. This suggests that our results may conservatively underestimate the full economic benefit to health systems. For patients and caregivers, prolonged recovery often results in lost productivity, reduced income, and QoL impacts that extend beyond the clinical setting.

This analysis adds to a growing body of evidence demonstrating the economic value of alternative wound and SSI reduction strategies in spine surgery. Prior evaluations of intrawound vancomycin powder suggest that it is cost-effective even with very small reductions in infection rates, given the high costs associated with readmission and revision surgery following SSI[15,16]. Similarly, closed-incisional negative pressure wound therapy has been shown to reduce wound dehiscence and SSI rates in high-risk spinal fusion patients, with a cost benefit analysis reporting meaningful net savings driven by avoidance of resource-intensive complications[39]. Collectively, evidence across these interventions indicate that reducing postoperative complications can yield meaningful economic value in high-risk spine surgery populations.

This analysis underscores how economic evaluation can guide resource allocation for quality improvement strategies that enhance outcomes and reduce avoidable costs[40]. As health systems transition toward value-based purchasing, performance is increasingly tied to metrics such as complication rates, readmissions, and overall cost of care[41]. By reducing surgical site complications and minimizing resource-intensive events, hydrolyzed collagen can contribute to these goals as an adjunctive to wound management, making it relevant and strategic addition to spine surgery protocols. For high-risk spinal surgery patients, proactive wound management using clinically effective, cost-saving adjuncts like hydrolyzed collagen can support better patient outcomes while improving payment performance under bundled reimbursement frameworks.

Limitations

As with any economic model, this study has limitations that should be considered when interpreting the findings. The model was structured to reflect an acute care pathway and employed a one-year time horizon, which excludes chronic conditions or long-term complications that may arise beyond this period. While the modeled population consisted of high-comorbidity patients, representing those most likely to benefit from an adjunctive wound intervention, the comorbidity profile used was not exhaustive. Therefore, the magnitude of benefit may differ in healthier or lower-risk surgical populations. Additionally, the model did not differentiate between wound and implant-related revisions, which are clinically distinct and may carry different implications for cost and outcomes.

Clinical input data also carry limitations related to heterogeneity in procedures, patient populations, and outcome definitions across the available evidence. Studies informing complication risk and treatment effectiveness spanned a range of anatomic regions (e.g. cervical and lumbar) and surgical complexity, with variable inclusion of elective versus revision cases and differing comorbidity profiles. In some studies, the treatment arm included administration of vancomycin, introducing potential confounders when interpreting complication rates[22,23]. As a result, the real-world effectiveness (risk reduction) of hydrolyzed collagen as a topical adjunct may vary depending on practice patterns, patient risk factors, and institutional protocols[24].

While hydrolyzed collagen has demonstrated clinical efficacy in published literature, both the baseline post-surgical complication rate and the modeled treatment effect rely on a synthesis of studies from related but not identical surgical populations. This approach introduces inherent variability but reflects a well-established and pragmatic method for economic evaluation when direct data are limited[42]. Additionally, individual studies informed certain key model parameters, such as the readmission rates

and disutility associated with complications[31,32]. However, varying these rates in the sensitivity analyses did not materially impact the model results.

Conclusions

This economic evaluation suggests that hydrolyzed collagen, as a topical adjunct for wound management in spine surgery, can promote both improved health outcomes and cost savings relative to standard care in a high-risk surgical population. The spine surgery bundle's value stems from its ability to reduce incident complications in a high-risk cohort, thereby lowering the need for additional interventions driving costly episodes of care. While the results should be interpreted in light of key assumptions and the evidence base, they remained consistent across sensitivity and threshold analyses, supporting their reliability and relevance within real-world clinical variability. Although the supporting literature included data from broader surgical contexts, this analysis focused exclusively on spine procedures to align with the modeled care pathway. Taken together, these findings support consideration of hydrolyzed collagen as a cost-effective and quality-enhancing adjunct for wound management within spinal surgery protocols. Future research should evaluate its clinical and economic impact in more pointed spine surgery subpopulations, given the inherent differences in cervical versus lumbar procedures and degenerative versus deformity cases.

Transparency

Declaration of funding

This research was funded by Sanara MedTech.

Declaration of financial/other interests

WVP declares personal fees and equity holdings with Stage Analytics. Unrelated to this work, WVP has also received funding support from PhRMA Foundation, BMS, and AbbVie. VM declares consulting fees with Sanara MedTech. BGC, and PS are employees of Stage Analytics which received funding from Sanara MedTech for conducting this study.

Peer reviewers on this manuscript have no relevant financial or other relationships to disclose.

Author contributions

VM and JEM provided strategic guidance on the study conceptualization/design. WVP provided strategic guidance and oversight on the study conceptualization/design, interpretation of results, and study execution. BGC, and PS executed the study with input from all authors.

Acknowledgements

None stated.

Data availability statement

All data that informed the model were drawn from peer-reviewed literature.

ORCID

William V. Padula http://orcid.org/0000-0003-1161-6954

References

[1] Mamdouhi T, Wang V, Echevarria AC, et al. A comprehensive review of the historical description of spine surgery and its evolution. Cureus. 2024;16(2):e54461. doi: 10.7759/cureus.54461.

[2] Härtl R. The 6 T's of minimally invasive spine surgery. Global Spine J. 2020;10(2 Suppl):5S–7S. doi: 10.1177/2192568220911617.
[3] Brintz CE, Coronado RA, Schlundt DG, et al. A conceptual model for spine surgery recovery: a qualitative study of patients' expectations, experiences, and satisfaction. Spine (Phila Pa 1976). 2023;48(14):E235–E244. doi: 10.1097/BRS.0000000000004520.
[4] Olsen MA, Nepple JJ, Riew KD, et al. Risk factors for surgical site infection following orthopaedic spinal operations. J Bone Joint Surg Am. 2008;90(1):62–69. doi: 10.2106/JBJS.F.01515.
[5] Butrico C, Meisel HJ, Sage K. Patient comorbidities, their influence on lumbar spinal fusion surgery, and recommendations to reduce unfavorable outcomes. J Am Acad Orthop Surg. 2024;32(24):1115–1121. doi: 10.5435/JAAOS-D-23-01167.
[6] Centers for Medicare & Medicaid Services. Hospital readmissions reduction program (HRRP). 2025 [accessed 2025 Sep 26]. https://www.cms.gov/medicare/payment/prospective-payment-systems/acute-inpatient-pps/hospital-readmissions-reduction-program-hrrp
[7] Prinz V, Vajkoczy P. Surgical revision strategies for postoperative spinal implant infections (PSII). J Spine Surg. 2020;6(4):777–784. doi: 10.21037/jss-20-514.
[8] Elgafy H, Vaccaro AR, Chapman JR, et al. Rationale of revision lumbar spine surgery. Global Spine J. 2012;2(1):7–14. doi: 10.1055/s-0032-1307254.
[9] Gerlach EB, Ituarte F, Plantz MA, et al. Predictive analysis of healthcare resource utilization after elective spine surgery. Spine Surg Relat Res. 2022;6(6):638–644. doi: 10.22603/ssrr.2022-0030.
[10] Philipp LR, Leibold A, Mahtabfar A, et al. Achieving value in spine surgery: 10 major cost contributors. Global Spine J. 2021;11(1_suppl):14S–22S. doi: 10.1177/2192568220971288.
[11] Edmiston CE, Jr, Leaper DJ, Chitnis AS, et al. Risk and economic burden of surgical site infection following spinal fusion in adults. Infect Control Hosp Epidemiol. 2023;44(1):88–95. doi: 10.1017/ice.2022.32.
[12] Hou Y, Collinsworth A, Hasa F, et al. Incidence and impact of surgical site infections on length of stay and cost of care for patients undergoing open procedures. Surg Open Sci. 2023;11:1–18. doi: 10.1016/j.sopen.2022.10.004.
[13] Blumberg TJ, Woelber E, Bellabarba C, et al. Predictors of increased cost and length of stay in the treatment of postoperative spine surgical site infection. Spine J. 2018;18(2):300–306. doi: 10.1016/j.spinee.2017.07.173.
[14] Goodman T, Spry C. Introduction to perioperative nursing. In: Goodman T, Spry C, editors. Essentials of perioperative nursing, 6th ed. Burlington (MA): Jones & Bartlett Learning; 2017. p. 1–14.
[15] Kerbel YE, Kirchner GJ, Sunkerneni AR, et al. The cost-effectiveness of vancomycin powder in lumbar laminectomy. Global Spine J. 2021;11(1):28–33. doi: 10.1177/2192568219888451.
[16] Emohare O, Ledonio CG, Hill BW, et al. Cost savings analysis of intrawound vancomycin powder in posterior spinal surgery. Spine J. 2014;14(11):2710–2715. doi: 10.1016/j.spinee.2014.03.011.
[17] León-López A, Morales-Peñaloza A, Martínez-Juárez VM, et al. Hydrolyzed collagen-sources and applications. Molecules. 2019;24(22):4031.
[18] Ricard-Blum S. The collagen family. Cold Spring Harb Perspect Biol. 2011;3(1):a004978–a004978. doi: 10.1101/cshperspect.a004978.
[19] Nowrouzi R, Awad SS. Activated collagen powder significantly reduces surgical site infections in patients undergoing elective surgery. J Surg. 2023;8:1918.
[20] Evans DC, Evans BG. The effects of platelet-rich plasma and activated collagen on wound healing in primary total joint arthroplasty. Orthopedics. 2018;41(2):e262–e267. doi: 10.3928/01477447-20180213-05.
[21] Gitelman A. The use of sterile bovine type 1 hydrolyzed collagen to support surgical wound management: a case series. JSM Neurosurg Spine. 2022;9(1):1108.
[22] Dickerman R, Reynolds AS, Winters K. Operative closure technique utilizing bovine collagen fragments in a prospective analysis of 102 consecutive neurosurgery patients. JSM Neurosurg Spine. 2017;5(2):1088.
[23] Hotchkiss WR. Retrospective study to evaluate the use of type 1 bovine hydrolyzed collagen to support surgical wound healing after spinal surgery. JSM Neurosurg Spine. 2021;8(1):1103.
[24] Sultan D, Goote P, Crowley C, et al. Retrospective cohort analysis on the use of hydrolyzed collagen powder in back reconstruction following spinal instrumentation. Eplasty. 2024;24:e25.
[25] Chang D, Zygourakis CC, Wadhwa H, et al. Systematic review of cost-effectiveness analyses in U.S. spine surgery. World Neurosurg. 2020;142:e32–e57. doi: 10.1016/j.wneu.2020.05.123.
[26] Eseonu K, Oduoza U, Monem M, et al. Systematic review of cost-effectiveness analyses comparing open and minimally invasive lumbar spinal surgery. Int J Spine Surg. 2022;16(4):612–624. doi: 10.14444/8297.
[27] Padula WV, Black JM, Davidson PM, et al. Adverse effects of the medicare PSI-90 hospital penalty system on revenue-neutral hospital-acquired conditions. J Patient Saf. 2020;16(2):e97–e102. doi: 10.1097/PTS.0000000000000517.
[28] Padula WV, Armstrong DG, Goldman DP. Complexity bias in the prevention of iatrogenic injury: why specific harms may inhibit performance. Mayo Clin Proc. 2022;97(2):221–224. doi: 10.1016/j.mayocp.2021.10.001.
[29] Poorman GW, Moon JY, Horn SR, et al. Rates of mortality in cervical spine surgical procedures and factors associated with its occurrence over a 10-year period: a study of 342 477 patients on the nationwide inpatient sample. Int J Spine Surg. 2018;12(2):276–284. doi: 10.14444/5034.

[30] Lange N, Stadtmüller T, Scheibel S, et al. Analysis of risk factors for perioperative complications in spine surgery. Sci Rep. 2022;12(1):14350. doi: 10.1038/s41598-022-18417-z.
[31] Ilyas H, Golubovsky JL, Chen J, et al. Risk factors for 90-day reoperation and readmission after lumbar surgery for lumbar spinal stenosis. J Neurosurg Spine. 2019;31(1):20–26. doi: 10.3171/2019.1.SPINE18878.
[32] Kuhns BD, Lubelski D, Alvin MD, et al. Cost and quality of life outcome analysis of postoperative infections after subaxial dorsal cervical fusions. J Neurosurg Spine. 2015;22(4):381–386. doi: 10.3171/2014.10.SPINE14228.
[33] Rubel NC, Chung AS, Wong M, et al. 90-day readmission in elective primary lumbar spine surgery in the inpatient setting: a nationwide readmissions database sample analysis. Spine (Phila Pa 1976). 2019;44(14): E857–E864. doi: 10.1097/BRS.0000000000002995.
[34] Yeramaneni S, Robinson C, Hostin R. Impact of spine surgery complications on costs associated with management of adult spinal deformity. Curr Rev Musculoskelet Med. 2016;9(3):327–332. doi: 10.1007/s12178-016-9352-9.
[35] Nayak NR, Stephen JH, Piazza MA, et al. Quality of life in patients undergoing spine surgery: systematic review and meta-analysis. Global Spine J. 2019;9(1):67–76. doi: 10.1177/2192568217701104.
[36] Shepard J, Frederick J, Wong F, et al. Could the prevention of health care-associated infections increase hospital cost? the financial impact of health care-associated infections from a hospital management perspective. Am J Infect Control. 2020;48(3):255–260. doi: 10.1016/j.ajic.2019.08.035.
[37] Marrache M, Harris AB, Raad M, et al. Preoperative and postoperative spending among working-age adults undergoing posterior spinal fusion surgery for degenerative disease. World Neurosurg. 2020;138:e930–e939. doi: 10.1016/j.wneu.2020.03.143.
[38] McCarthy IM, Hostin RA, Ames CP, et al. Total hospital costs of surgical treatment for adult spinal deformity: an extended follow-up study. Spine J. 2014;14(10):2326–2333. doi: 10.1016/j.spinee.2014.01.032.
[39] Kramer DE, Bharthi R, Myers D, et al. Prophylactic closed-incisional negative pressure wound therapy following posterior instrumented spinal fusion: a single surgeon's experience and cost-benefit analysis. Neurosurg Rev. 2024;47(1):847. doi: 10.1007/s10143-024-03083-8.
[40] Padula WV, Lee KKH, Pronovost PJ. Using economic evaluation to illustrate value of care for improving patient safety and quality: choosing the right method. J Patient Saf. 2021;17(6):e568–e574. doi: 10.1097/PTS.0000000000000410.
[41] Hines K, Mouchtouris N, Getz C, et al. Bundled payment models in spine surgery. Global Spine J. 2021;11(1_suppl):7S–13S. doi: 10.1177/2192568220974977.
[42] Padula WV, Pronovost PJ, Makic MBF, et al. Value of hospital resources for effective pressure injury prevention: a cost-effectiveness analysis. BMJ Qual Saf. 2019;28(2):132–141. doi: 10.1136/bmjqs-2017-007505.

The unapproved use(s) of the medical product has not been reviewed by FDA and the safety and effectiveness of the medical device for the unapproved uses(s) has not been established.