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The Cost-Effectiveness of Vancomycin Powder in Lumbar Laminectomy

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Abstract

Study Design: Break-even cost analysis.

Objective: The goal of this study is to examine the cost-effectiveness of vancomycin powder for preventing infection following lumbar laminectomy.

Methods: The product cost of vancomycin powder was obtained from our institution's purchasing records. Infection rates and revision costs for lumbar laminectomy and lumbar laminectomy with fusion were obtained from the literature. A break-even analysis was then performed to determine the absolute risk reduction (ARR) in infection rate to make prophylactic application of vancomycin powder cost-effective. Analysis of lumbar laminectomy with fusion was performed for comparison.

Results: Costing $3.06 per gram at our institution, vancomycin powder was determined to be cost-effective in lumbar laminectomy if the infection rate of 4.2% decreased by an ARR of 0.015%. Laminectomy with fusion was also determined to be cost-effective at the same cost of vancomycin powder if the infection rate of 8.5% decreased by an ARR of 0.0034%. The current highest cost reported in the literature, $44.00 per gram of vancomycin powder, remained cost-effective with ARRs of 0.21% and 0.048% for laminectomy and laminectomy with fusion, respectively. Varying the baseline infection rate did not influence the ARR for either procedure when the analysis was performed using the product cost of vancomycin at our institution.

Conclusions: This break-even analysis demonstrates that prophylactic vancomycin powder can be highly cost-effective for lumbar laminectomy. At our institution, vancomycin powder is economically justified if it prevents at least one infection out of 6700 lumbar laminectomy surgeries.

Keywords

cost-benefit analysis, economic models, laminectomy, lumbar, vancomycin

Introduction

Infection following lumbar laminectomy with fusion is both devastating and costly.[1] The average cost of revision following an infected lumbar laminectomy with fusion has recently been reported as $90 938.[2] The rates of infection with different organisms following spine surgery vary by study; however, some of the most frequent organisms identified are gram-positive cocci including methicillin-resistant *Staphylococcus aureus* (MRSA) and *Staphylococcus epidermidis*.[3] Increasing methicillin resistance has decreased the efficacy of intravenous cephalosporins as the standard preoperative antibiotic prophylaxis used in orthopedic procedures in general, and spine surgery in particular.[3-5]

Studies have reported that more than 60% of wound infection isolates in the United States are cephalosporin-resistant, including MRSA and coagulase-negative *Staphylococcus*.[6,7] Among orthopedic patients in the United States, 20% to 30%

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have anterior nares colonized by methicillin-sensitive *S aureus* (MSSA), and 2% to 6% are colonized by MRSA.[8] Patients colonized preoperatively with MSSA face an added risk of surgical site infection 9 to 10 times greater than those who are not colonized, whereas patients preoperatively colonized with MRSA face an added risk of up to 4 times greater than those colonized with MSSA.[8] The incidence of MRSA colonization among orthopedic patients is particularly concerning due to the virulent nature of the microbe. It not only poses a greater risk but is also more difficult to treat and, as a result, more expensive to the health care system.[9] Rising prevalence of methicillin resistance and recognition of *S aureus* colonization as a modifiable risk factor for wound infection has resulted in a growing adoption of prophylactic antibiotic usage in spine surgery to prevent infection with *S aureus* and other gram-positive microbes.[10,11]

In particular, vancomycin powder has been added as a local application in wound beds for cardiac, vascular, spine, and a variety of other orthopedic procedures.[10,11] The effect has been a demonstrable decrease in infection without any appreciable complications.[12,13] Sweet et al found that the addition of vancomycin powder to traditional intravenous antibiotics reduced the deep infection rate after thoracic and lumbar instrumented spinal fusions from 2.6% to 0.2%, with no adverse clinical or wound complications.[13] Other studies have found a decrease in infection from 15% to 0% with the addition of vancomycin powder in instrumented posterior cervical spine fusions and a decrease from 13% to 0% when vancomycin was added to posterior spinal fusions for trauma.[14,15]

The cost-effectiveness of vancomycin powder as a means of infection prophylaxis in lumbar laminectomy with fusion has been assessed in prior studies. In a retrospective review of 110 patients with traumatic spine injuries treated with instrumented posterior spine fusions over a 2-year period at a single institution, Godil et al[16] found that vancomycin powder led to cost-savings of $438 165 per 100 spinal fusions performed, while Emohare et al[17] found that their use of vancomycin powder in posterior instrumented spine surgery saved their hospital more than $500 000 over a 2-year span.

However, to our knowledge, no prior studies have examined the cost-effectiveness of vancomycin powder when utilized specifically for simple laminectomy without concomitant fusion. The goal of this study was to examine the cost-effectiveness of vancomycin powder in lumbar laminectomy without fusion using a simple break-even cost analysis that any spine surgeon can utilize to determine the exact economic viability of intraoperative vancomycin powder for their specific practice. This study also compared the cost-effectiveness of vancomycin powder for lumbar laminectomy in comparison to lumbar laminectomy with fusion to determine the degree to which the added fusion procedure changes the overall break-even economic calculations.

Materials and Methods

As an economic model for determining cost-effectiveness, we utilized a break-even analysis originally described by Hatch et al (Figure 1).[18] This equation produces the final break-even infection rate necessary to make a protocol cost-effective, given the initial infection rate, the total cost of treating an infection, and the cost of a treatment or prevention protocol. These values were determined from the literature and our institution's purchasing records. Calculating the difference between the initial and final infection rates yields the absolute risk reduction (ARR), which is the percent by which a protocol must reduce the infection rate to economically justify its use as a prophylactic measure. Clinicians can tailor this equation to their practice, by using their preferred method and institutional product costs, to determine the ARR of their given protocol.

$$S_{total} \times C_t \times IR_i = (S_{total} \times C_d) + (S_{total} \times C_t \times IR_f)$$

Solving for IR_f yields:

$$IR_f = \frac{(IR_i \times C_t) - C_d}{C_t}$$

Figure 1. Equation used to calculate the break-even infection rate. Where: S_{total} = total annual surgeries; C_t = total cost of treating an infection; C_d = cost of drug; IR_i = initial infection rate; IR_f = breakeven infection rate. Adapted from Hatch et al.[18]

Prior studies have shown drastically different rates of both infection and cost of revision when comparing lumbar laminectomy with fusion to simple laminectomy alone. Reported literature values for baseline infection rates after lumbar laminectomy with fusion are 8.50%, while infection rates from lumbar laminectomy alone are 4.20%.[2,19] The average total hospital cost of revision following infection after lumbar laminectomy with fusion has been reported as $90 938, while the total hospital cost of revision for infected lumbar laminectomy alone is much lower at $21 060.[20,21] The product cost of vancomycin powder was obtained from our institution's purchasing records and was found to be $3.06 per gram. Within the literature, the cost of vancomycin powder was found to range from $2.50 to $44.[13,16-18,22,23]

Results

Costing $3.06 per gram at our institution, vancomycin powder was determined to be cost-effective in lumbar laminectomy if the infection rate of 4.2% decreased by an ARR of 0.015% (Table 1). Laminectomy with fusion was determined to be cost-effective at the same cost of vancomycin powder if the infection rate of 8.5% decreased by an ARR of 0.0034%. The current highest cost of vancomycin reported in the literature, $44.00 per gram, was cost-effective with ARRs of 0.21% and 0.048% for laminectomy alone and laminectomy with fusion, respectively.

Additional calculations were performed using a wide range of infection rates, taking into consideration the fact that infection rates after lumbar procedures vary in the literature and are also presumed to vary by institution and surgeon. For these

Table 1. Cost-Effectiveness of Prophylactic Vancomycin Powder for Lumbar Laminectomy.

	Laminectomy		Laminectomy and Fusion	
Vancomycin Powder (1 g) Cost (US$)	Break-Even Infection Rate (%)	Break-Even ARR (%)	Break-Even Infection Rate (%)	Break-Even ARR (%)
2.50	4.19	0.01	8.50	0.003
3.06[a]	4.19	0.01	8.50	0.003
10.00	4.15	0.05	8.49	0.01
17.00	4.12	0.08	8.48	0.02
34.00	4.04	0.16	8.46	0.04
44.00	3.99	0.21	8.45	0.05
50.00	3.96	0.24	8.45	0.05
75.00	3.84	0.36	8.42	0.08
100.00	3.73	0.47	8.39	0.11

Abbreviation: ARR, absolute risk reduction.
[a]Value at our institution.

Table 2. Maintaining Cost of Vancomycin[a] and the Cost of Treating Infection Constant Does Not Change Cost-Effectiveness.

	Laminectomy		Laminectomy and Fusion	
Initial Infection Rate[b] (%)	Final Infection Rate (%)	ARR (%)	Final Infection Rate (%)	ARR (%)
0.50	0.49	0.0145	0.50	0.0034
1	0.99	0.0145	1.00	0.0034
2	1.99	0.0145	2.00	0.0034
3	2.99	0.0145	3.00	0.0034
4	3.99	0.0145	4.00	0.0034
5	4.99	0.0145	5.00	0.0034
6	5.99	0.0145	6.00	0.0034
7	6.99	0.0145	7.00	0.0034
8	7.99	0.0145	8.00	0.0034
9	8.99	0.0145	9.00	0.0034
10	9.99	0.0145	1.00	0.0034

Abbreviation: ARR, absolute risk reduction.
[a]Cost of vancomycin $3.06 per gram at our institution.
[b]Presumes cost of treating infection is $21 060 for laminectomy and $90 938 for laminectomy and fusion.

analyses, the costs of revision following infection after both procedures were held constant. These calculations demonstrated that even at initial infection rates as high as 10%, the cost-effectiveness of vancomycin powder in both procedures remained unchanged with an ARR of 0.015% for lumbar laminectomy alone and 0.0034% for laminectomy with fusion (Table 2).

To determine how much impact the cost of revision had on the break-even analysis, the ARR was calculated when the initial rate of infection and the cost of vancomycin powder was held constant across various costs of revision. The results showed that the ARR does vary based on the revision rate, but most of the variation is at extremes of cost and is not clinically relevant (Table 3).

Table 3. Maintaining Cost of Vancomycin[a] and Initial Rate of Infection[b] Constant Changes Cost-Effectiveness.

	Laminectomy		Laminectomy and Fusion	
Cost of Treating Infection (US$)	Final Infection Rate (%)	ARR (%)	Final Infection Rate (%)	ARR (%)
500	3.59	0.6120	7.89	0.6120
1000	3.89	0.3060	8.19	0.3060
5000	4.14	0.0612	8.44	0.0612
10 000	4.17	0.0306	8.47	0.0306
21 060[c]	4.19	0.0145	8.49	0.0145
30 000	4.19	0.0102	8.49	0.0102
40 000	4.19	0.0077	8.49	0.0076
50 000	4.19	0.0061	8.49	0.0061
75 000	4.20	0.0041	8.50	0.0041
90 938[d]	4.20	0.0034	8.50	0.0034
100 000	4.20	0.0031	8.50	0.0031
120 000	4.20	0.0025	8.50	0.0025

Abbreviation: ARR, absolute risk reduction.
[a]Cost of vancomycin $3.06 per gram at our institution.
[b]Presumes initial rate of infection is 4.20% for laminectomy and 8.50% for laminectomy and fusion.
[c]Denotes literature value of treating infected laminectomy.
[d]Denotes literature value of treating infected laminectomy and fusion.

Discussion

The intra-wound application of vancomycin powder has been utilized for infection prophylaxis across a variety of surgical specialties, including multiple subspecialties of orthopedic surgery.[10,11] The effect has been a demonstrable decrease in infection without any appreciable complications.[12,13] With regard to spine surgery, Sweet et al demonstrated that vancomycin powder reduced the deep infection rate after thoracic and lumbar instrumented spinal fusions from 2.6% to 0.2% compared to traditional intravenous antibiotics, with no adverse clinical or wound complications.[13] Additional studies have reported precipitous decreases in infection rates with vancomycin powder prophylaxis in spine surgeries, such as instrumented posterior cervical spine fusions (15% to 0%), posterior spinal fusions for trauma (13% to 0%), and complex posterior instrumented spine surgery (10% to 5%).[14,15,24]

Given the recent economic changes in orthopedic reimbursement, including the trend toward bundle payments, minimizing costs while improving efficacy and patient outcomes is more important than ever before.[25-27] There is a dearth of published data on the economic burden of infection after lumbar laminectomy with fusion, but the limited studies that have described these costs have uniformly shown the tremendous economic burden of an infected spinal surgery, particularly with implants.[1] A recent study by Patel et al identified postoperative spinal infection as one of the most expensive causes of readmission and concluded that patients with spine surgery incur approximately double the health care costs when they develop a surgical site infection.[28]

The most common organism causing infection after lumbar laminectomy with fusion is *S aureus*, estimated to account for

up to 90% of all infection following these operations.[28] The incidence of MRSA in spinal surgery has been found to account for an estimated 25% to 52% of all *S aureus* isolates from infected spine procedures.[28] Infection with this microorganism is particularly worrisome, as prior studies have shown that treatment outcomes are less successful and more costly for patients.[9,29] Thus, there has been an increased focus on preventing MRSA infections after lumbar laminectomy with fusion by utilizing local vancomycin powder intraoperatively.[12,22,30]

In addition to its advantageous antimicrobial properties, vancomycin powder has also gained popularity due to its cost-effectiveness.[16,17] However, prior cost-effectiveness studies have looked at cost-effectiveness either from a macroeconomic standpoint or utilizing institution-specific values that may not apply to other practices.[16,17] In addition, prior studies have looked at the cost-effectiveness of vancomycin powder for laminectomy with instrumented fusion but have failed to examine the cost-effectiveness in laminectomy alone or to provide a cost-effectiveness comparison between the 2 procedures.

Despite the growing body of evidence supporting the efficacy of vancomycin powder for infection prophylaxis in orthopedic surgery, many researchers remain concerned regarding the routine prophylactic use of a potent antimicrobial agent. In a recent investigation of patients who underwent irrigation and debridement of wound infections following elective thoracic or lumbar surgery, Grabel et al found that polymicrobial infections and infection with gram-negative organisms was significantly more common among patients who had received vancomycin powder prophylaxis during the index procedure.[31] Nevertheless, Grabel et al did not appreciate any differences between infected spine patients who received vancomycin powder and those who did not regarding rate of requiring greater than one antibiotic to treat the infection. However, the rate of repeated irrigation and debridement was significantly less in the vancomycin-treated group.[31]

There are a few important considerations derived from this break-even equation. First, the major determinant of cost-effectiveness is the cost of the vancomycin powder itself. At our institution, the cost of the powder was low at $3.06; however, even at inflated values as high as $44.00, it remained cost-effective for both procedures. Second, the baseline infection rate does not affect the ARR obtained at any specific cost of vancomycin powder. When both the cost of treating an infection and the cost of the powder were kept constant, the final break-even ARR remained unchanged for both procedures, regardless of initial infection rate. Finally, the cost of treating an infection does make a difference, but the difference is probably subclinical at the current cost levels estimated in the literature. When the cost of vancomycin powder and the initial infection rates were kept constant, the ARR for vancomycin powder varied very little when calculated within the cost ranges of treating an infection cited in the literature.

The utility of this break-even equation is that it provides a straightforward method to determine the economic viability of vancomycin powder for lumbar laminectomy with and without fusion, even though the incidence of infection is low enough to preclude a randomized controlled trial. For instance, assuming that vancomycin powder has a hypothetical ARR of 0.02%, the number needed to treat to prevent an infection would be 1 in 5000. To determine this same result in a clinical trial using a power analysis, the sample size, assuming $P < .05$ and power = 80%, would need to be extremely high (15 366 400). In our case, even with the most expensive vancomycin powder cost, which requires the largest ARR of 0.21% for laminectomy without fusion, the sample size remains prohibitively large at 139 378. Likewise, laminectomy with fusion, which requires an ARR of 0.048% at the most expensive cost of vancomycin, would require an even larger sample size of 2 667 778, which is an impossible number of patients to follow in a clinical study. Thus, this equation serves as an extremely useful tool for any clinician to determine the cost-effectiveness of intraoperative vancomycin powder utilization, both in simple lumbar laminectomy and in any other spine procedure. All the clinician requires is their initial infection rate, the costs of surgical revision for a given procedure at their institution, and their purchasing costs for vancomycin powder, and they can calculate the cost-effectiveness of vancomycin powder for any procedure used in their own practice.

Based on our results, we believe that vancomycin powder is a cost-effective measure for the prevention of infection in both lumbar laminectomy with fusion and lumbar laminectomy alone, although it is more cost-effective when used for laminectomy with fusion. Despite the fact that the efficacy of vancomycin powder has not been directly examined in simple lumbar laminectomy, its efficacy has been documented in noninstrumented lumbar procedures.[22] The choice to utilize this modality intraoperatively should be a multifactorial decision that includes individualized patient and physician decision making, as well as institutional infection rates and protocols. It is important to note that we are not recommending that all institutions utilize vancomycin powder in all their laminectomy procedures. This article simply aims to serve as an objective cost-analysis model for physicians to use when considering the financial aspects of their spine surgery infection prevention algorithm.

While this study provides a useful framework for any clinician to improve the cost-effectiveness of their practice, it contains several flaws. First, the cost and infection data are not exact and are liable to fluctuate between different institutions. Our infection data was based on national estimates provided in the literature, which may vary greatly by practice and patient population. Second, this study only considers a single type of spine surgery and may not be generalizable to other spinal procedures or differing techniques, such as minimally invasive versus open. Third, modelling can only account for averages and does not include individualized patient and regional demographics. We believe, however, that this model still provides a useful conceptual framework for overall practice management that can be deviated from for anomalous or complex patients. Finally, our study does not consider the noneconomic aspects of these protocols, such as antibiotic resistance and the wider

public health implications of using vancomycin powder in all patients. We deliberately chose to focus this article solely on the economic implications of this treatment protocol.

This break-even analysis demonstrates that prophylactic intra-wound application of vancomycin powder can be highly cost-effective not only for lumbar laminectomy with fusion but also for laminectomy alone. At our institution's price point, the use of vancomycin powder is economically justified if it prevents at least one infection out of 6667 lumbar laminectomy surgeries. By comparison, the use of vancomycin powder in lumbar laminectomy with fusion would be cost-effective if it prevented at least one infection out of 29 411 surgeries. Additionally, the baseline infection rate did not affect the ARR of the protocols studied, with the ARR of vancomycin powder remaining constant at both extremely low and high initial infection rates. Finally, the cost of treating an infection did affect the ARR of the protocols studied when extreme values were used but had no clinical significance at the average cost ranges cited in the literature. This break-even analysis is easily adaptable to the individual practices of academic institutions or private practice surgeons, providing a useful economic analysis tool for the practicing spine surgeon.

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