An Economic Model: Value of Antimicrobial-Coated Sutures to Society, Hospitals, and Third-Party Payers in Preventing Abdominal Surgical Site Infections

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original article

An Economic Model: Value of Antimicrobial-Coated Sutures to Society, Hospitals, and Third-Party Payers in Preventing Abdominal Surgical Site Infections

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background. While the persistence of high surgical site infection (SSI) rates has prompted the advent of more expensive sutures that are coated with antimicrobial agents to prevent SSIs, the economic value of such sutures has yet to be determined.

methods. Using TreeAge Pro, we developed a decision analytic model to determine the cost-effectiveness of using antimicrobial sutures in abdominal incisions from the hospital, third-party payer, and societal perspectives. Sensitivity analyses systematically varied the risk of developing an SSI (range, 5%–20%), the cost of triclosan-coated sutures (range, $5–$25/inch), and triclosan-coated suture efficacy in preventing infection (range, 5%–50%) to highlight the range of costs associated with using such sutures.

results. Triclosan-coated sutures saved $4,109–$13,975 (hospital perspective), $4,133–$14,297 (third-party payer perspective), and $40,127–$53,244 (societal perspective) per SSI prevented, when a surgery had a 15% SSI risk, depending on their efficacy. If the SSI risk was no more than 5% and the efficacy in preventing SSIs was no more than 10%, triclosan-coated sutures resulted in extra expenditure for hospitals and third-party payers (resulting in extra costs of $1,626 and $1,071 per SSI prevented for hospitals and third-party payers, respectively; SSI risk, 5%; efficacy, 10%).

conclusions. Our results suggest that switching to triclosan-coated sutures from the uncoated sutures can both prevent SSIs and save substantial costs for hospitals, third-party payers, and society, as long as efficacy in preventing SSIs is at least 10% and SSI risk is at least 10%.

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Antimicrobial surgical sutures are a relatively new intervention to prevent surgical site infections (SSIs), the second most common hospital-acquired infections in the United States.[1] This intervention emerged because SSIs remain a continuing major problem despite the various existing infection measures.[2,3] Intra-abdominal surgeries are especially associated with a high SSI rate (approximately 15%,[4] depending on procedure).[5-7] Since approximately 4 million out of the 51.4 million surgeries performed annually in the United States are open abdominal surgeries,[8] preventing SSIs for such surgeries may be highly beneficial.

Since suture material may be a potential medium for infection,[9,10] there is increasing interest in employing antibacterial sutures to lower SSI risk. Recent studies have found the efficacy of triclosan-coated sutures (Vicryl Plus, PDS Plus, and Monocryl Plus) in preventing SSIs to be variable.[11-22] These mixed findings and the higher cost of triclosan-coated sutures may limit their wholesale adoption. It could be that such sutures are best used under certain circumstances. For example, triclosan-coated sutures may be particularly useful for abdominal surgeries, because most involve clean-contaminated wounds; ie, the operative procedure enters into a colonized viscus or cavity of the body but under elective and controlled circumstances. To identify the situations for which such sutures may be appropriate, we developed a decision analytic simulation model to determine the cost and health effects of triclosan-coated absorbable sutures, as compared to those of their uncoated counterparts, for prevention of incisional infections in abdominal surgeries.

METHODS

Using TreeAge Pro 2013, we developed a decision analytic model (Figure 1) to simulate the decision of choosing triclosan-coated sutures versus the standard uncoated sutures for adult patients undergoing abdominal surgeries. Table 1 lists the model inputs, their values, and their distributions. Each patient entering the model underwent an abdominal surgery

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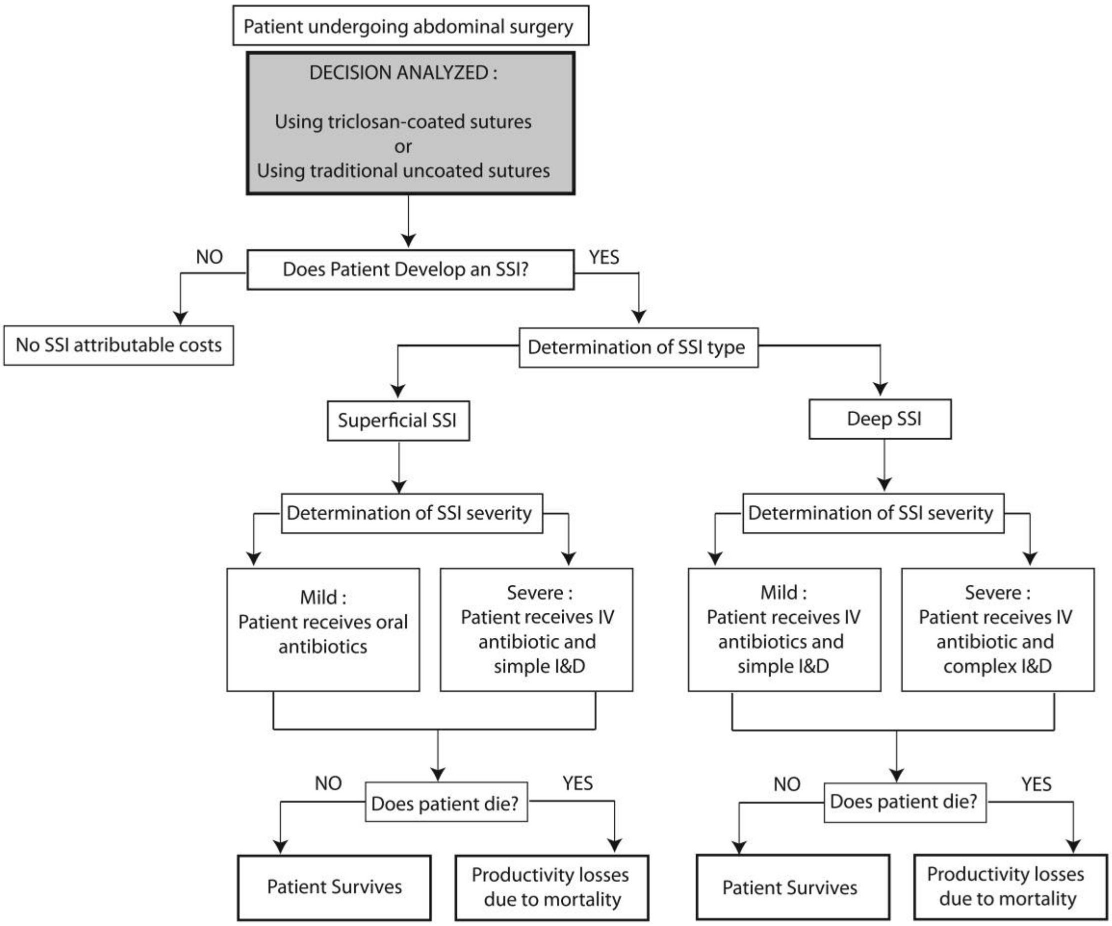

FIGURE 1. Model outline. SSI, surgical site infection; IV, intravenous; I&D, incision and drainage.

and had a risk of developing an incisional SSI. The SSI could be either superficial or deep and could be either mild or severe. Superficial infections are defined as those that occur within 30 days of a procedure involving only the skin and subcutaneous tissues, whereas deep incisional infections are more severe, including those that occur within 30 or 90 days after an operative procedure involving deeper soft tissues (fascial muscles). Patients who developed an SSI had an extended attributable length of stay and an increased mortality rate, depending on the type of SSI. The amount of suture used for each surgery was assumed to be 4 times the incision length, as recommended by previous studies.[24,39,40]

SSI treatment was dependent on the severity and type of SSI. Patients with a mild superficial SSI were treated with oral antibiotics, whereas those with severe superficial SSIs were administered intravenous (IV) antibiotics, along with simple incision and drainage (I&D). All patients with a deep incisional SSI were administered IV antibiotics. Along with antibiotic treatment, deep incisional SSIs that were mild in severity were treated with simple percutaneous I&D, whereas severe ones were treated with complex I&D. Antibiotic regimens were determined using Micromedex[30] and UpToDate[29] (refined by expert opinion). Oral antibiotics included broad-spectrum antibiotics such as metronidazole (500 mg every 6–8 hours) and ciprofloxacin (500 mg every 12 hours). IV antibiotics included vancomycin (15–20 mg/kg every 6–12 hours), linezolid (600 mg every 12 hours), ampicillin/sulbactam (1.5–3 mg every 6 hours), ceftriaxone (1–2 g every 12–24 hours), or piperacillin/tazobactam (3.375 g every 6–8 hours), depending on the causative pathogen and infection severity. Antibiotic treatment duration ranged from 7 to 14 days. On occasions where the patient was undergoing IV antibiotic treatment and treatment duration exceeded the hospital stay, his/her treatment was switched to oral antibiotics a day prior to discharge.

Separate analyses were carried out from the hospital, third-party payer, and societal perspectives to determine the economic benefits of using antimicrobial-coated sutures. The hospital perspective accounted for the suture costs and the opportunity cost of bed-days lost because of the increased length of stay associated with both superficial and deep SSIs,[41-43] bed-days that could have been filled by another pa-

TABLE 1. Model Inputs and Parameters

Parameter	Distribution type	Mean/median	Standard deviation/ range	References
Probabilities				
Surgical site infection (SSI)	…	0.15	…	Alexander et al[23]
Superficial SSI	β	0.697	0.305	Watanabe et al,[5] Baracs et al,[11] Millbourn et al,[24] Coello et al[25]
Deep SSI	β	0.302	0.305	Watanabe et al,[5] Baracs et al,[11] Millbourn et al,[24] Coello et al[25]
Severe SSI within each type	U	…	0.20–0.30	Expert opinion
Death due to superficial SSI	β	0.039	0.024	Coello et al,[25] Astagneau et al[26]
Death due to deep SSI	…	0.057	…	Astagneau et al[26]
Durations, days				
Length of hospitalization due to superficial SSI	γ	6.22	4.25	Coello et al,[25] Fukuda et al[27]
Length of hospitalization due to deep SSI	γ	9.675	0.96	Fukuda et al,[27] Merle et al[28]
Antibiotic treatment	U	…	7–14	UpToDate,[29] Micromedex,[30] expert opinion
Costs, US $				
Triclosan-coated suture	γ	9.93	6.39	Medical supply pricing[31,32]
Regular absorbable suture	γ	7.32	3.175	Medical supply pricing[31,32]
Hospitalization due to SSI				Healthcare Cost and Utilization Project[33]
1–17 years	γ	12,318	1,013	
18–44 years	γ	12,429	418	
45–64 years	γ	15,299	443	
65–84 years	γ	17,025	488	
85+ years	γ	15,164	663	
Simple incision and drainage	γ	98.32	7.63	AMA's CPT Code/Relative Value Search[34]
Complex incision and drainage	γ	185.52	15.03	AMA's CPT Code/Relative Value Search[34]
Intravenous insertion	…	9.53	…	AMA's CPT Code/Relative Value Search[34]
Intravenous antibiotic[a]	γ	51.03	70.00	Physicians' Desk Reference *Red Book*[35]
Oral antibiotics[b]	γ	13.65	12.81	Physicians' Desk Reference *Red Book*[35]
Mortality	Δ	7,563	5,672–9,862	Gould et al[36]
Productivity losses due to death[c]	…	…	139,801–1,483,215	Human Mortality Database[37]
Hourly wage	Δ	9.29	20.32–93.42	Bureau of Labor Statistics[38]

NOTE. AMA, American Medical Association; CPT, current procedural terminology.
[a] Intravenous antibiotics include vancomycin, linezolid, piperacillin/tazobactam, ceftriaxone, ampicillin, and sulbactam.
[b] Oral antibiotics include ciprofloxacin and metronidazole.
[c] Depending on age.

tient. The third-party payer perspective included the direct hospitalization and treatment costs, along with suture costs. The societal perspective included both direct (ie, hospitalization costs, treatment costs) and indirect costs (ie, productivity loss due to absenteeism and mortality and general mortality costs that include operational costs related to death, such as transportation and burial). Productivity losses were based on median hourly and annual wages for all occupations (assuming an 8-hour work day and a 5-day work week) for the duration of hospitalization. In addition, death resulted in the net present value of lost wages for the remainder of the person's life expectancy based on his/her age.[37] All costs were discounted to 2013 values using a 3% discount rate. The following formula determined the cost per SSI prevented:

$$\text{cost per SSI prevented} = \frac{\text{cost (coated)} - \text{cost (uncoated)}}{\text{no. of SSIs (coated)} - \text{no. of SSIs (uncoated)}}.$$

Each simulation run sent 1,000 individuals undergoing an abdominal surgery through the model 1,000 times (1,000,000 total trials). Sensitivity analyses systematically varied the risk of developing an SSI (range, 5%–20%) to account for heterogeneity among different surgical techniques and the presence/absence of various presurgical antibiotic prophylaxis regimens. Additional analyses varied triclosan-coated suture cost (range, $5–$25/inch) and efficacy (range, 5%–50%). The wide range of efficacy values accounted for the debate over the true efficacy of the sutures. Experts speculate that antimicrobial-coated sutures will be more effective in preventing superficial SSIs than in preventing deep incisional SSIs, so we also varied the efficacy of preventing superficial (range, 10%–50%) and deep incisional (range, 5%–20%) SSIs differentially. Monte Carlo probabilistic sensitivity analysis simultaneously varied all parameters throughout their ranges in Table 1.

RESULTS

Hospital Perspective

Table 2 shows the cost per SSI prevented when triclosan-coated sutures were used for an 8-inch-long incision, varying the risk of SSI. Triclosan-coated sutures that were 5% efficacious incurred extra costs when used for surgeries having at most a 10% SSI risk, resulting in an average expenditure of $46 (5% SSI risk) or $8 (10% SSI risk) per surgery. However, triclosan-coated sutures progressively saved greater costs per surgery (compared to uncoated sutures) when used for surgeries with an SSI risk of at least 15%, even with an efficacy as low as 5% (saving $30/surgery and preventing 7 SSIs/1,000 surgeries at 5% efficacy, which increased to saving $1,046/surgery and preventing 75 SSIs/1,000 surgeries at 50% efficacy). When used for surgeries with a higher infection risk, triclosan-coated sutures prevented a greater number of SSIs and consequently prevented their related costs.

A lower suture cost ($5 vs the current price, $9.93, per inch) generated even more cost savings, leading to an additional savings of at least $150 per surgery; less expensive triclosan-coated sutures resulted in cost savings per surgery even if only 5% efficacious, saving $186 per surgery with a 15% SSI risk. The costs savings per abdominal surgery increased linearly with increasing efficacy. Cost savings would decrease proportionately with higher-priced sutures. A more expensive triclosan-coated suture, costing at least $20 per inch, resulted in cost savings per surgery only if they had an efficacy of at least 20% (saving $48/surgery when costing $20/inch).

The costs associated with triclosan-coated suture use for various scenarios changed if they were assumed to prevent only superficial SSIs. Sutures that prevented only superficial SSIs for surgeries having a 15% SSI risk were not cost-effective at 5% efficacy, incurring an extra cost of $2,885 per SSI prevented. An increase in efficacy to prevent superficial SSIs resulted in rapid increases in costs saved per SSI prevented, as superficial SSIs are more common. Table 3 shows the costs saved per SSI averted with sutures having a differential efficacy to prevent superficial and deep incisional SSIs.

Third-Party Payer Perspective

Third-party payers saved slightly more costs per SSI prevented than did hospitals (Table 2) but followed a similar trend. For a 15% SSI risk, triclosan-coated sutures resulted in 7–14 SSIs per 1,000 surgeries, while traditional uncoated sutures resulted in approximately 15 SSIs per 1,000 surgeries, thus saving $4,133 (5% efficacious) to $14,297 (50% efficacious) per SSI prevented. The trend of cost saved per surgery for varied costs and efficacies of triclosan-coated sutures were also similar to those from the hospital perspective.

TABLE 2. Costs per SSI Averted for Varied Efficacies of Antimicrobial-Coated Sutures to Prevent SSI and Risk of Developing SSI for an 8-Inch[44] Incision from the Hospital, Third-Party Payer, and Societal Perspectives

	Risk of SSI			
Efficacy of the coated sutures, %	5%	10%	15%	20%
Hospital perspective				
5	18,870	1,625	−4,019	−6,689
10	1,626	−6,685	−9,497	−11,059
15	−3,750	−9,555	−11,515	−12,378
25	−8,560	−11,650	−12,936	−13,494
50	−11,784	−13,529	−13,975	−14,309
Third-party perspective				
5	17,687	1,280	−4,133	−7,198
10	1,071	−6,879	−9,750	−11,242
15	−4,474	−9,821	−11,652	−12,683
25	−8,773	−12,035	−13,170	−13,730
50	−12,036	−13,740	−14,297	−14,577
Societal perspective				
5	−23,519	−38,198	−40,127	−46,847
10	−46,779	−46,207	−50,187	−52,187
15	−47,291	−49,151	−51,724	−52,382
25	−47,303	−50,902	−52,424	−53,698
50	−51,759	−53,160	−53,244	−54,704

NOTE. Costs are presented in US dollars. Negative costs indicate cost savings. SSI, surgical site infection.

Societal Perspective

Using triclosan-coated sutures for surgeries having a 15% risk of SSI saved $40,127–$53,244 per SSI prevented, depending on efficacy (Table 2). For such surgeries, triclosan-coated sutures (5% efficacy) saved $296 per surgery while preventing 0.29 deaths per 1,000 surgeries; this increased to savings of $4,001 per surgery and prevention of 3.2 deaths per 1,000 surgeries at an efficacy of 50%. This shows that an intervention that can reduce number of deaths, even marginally, can lead to substantial cost savings.

Triclosan-coated sutures with a 5% efficacy, priced at $5 per inch, resulted in savings of $492 per surgery. A $15-per-inch triclosan-coated suture (efficacy > 5%) also resulted in cost savings per surgery. Such a triclosan-coated suture with 25% efficacy saved $1,745 per surgery while preventing 37 SSIs per 1,000 surgeries. Using triclosan-coated sutures with 5% efficacy resulted in extra costs of $34 and $171 per surgery if the suture costs further increased to $20 and $25 per inch, respectively. A 5% increase in triclosan-coated-suture efficacy increased the cost saved per surgery by more than $300, so at efficacies of at least 10% these more expensive sutures resulted in costs saved per surgery.

TABLE 3. Costs per SSI Averted from Hospital Perspective for Differential Efficacies of Antimicrobial-Coated Sutures to Prevent Superficial and Deep Incisional SSI and Associated Risk of Infection for an 8-Inch Incision

	Risk of developing SSI			
Efficacy	5%	10%	15%	20%
To prevent superficial SSI, 10%				
To prevent deep SSI, 0%	2,558	−957	−5,131	−6,848
To prevent deep SSI, 5%	5,710	−4,491	−7,592	−9,446
To prevent superficial SSI, 15%				
To prevent deep SSI, 0%	2,731	−4,751	−7,641	−9,002
To prevent deep SSI, 5%	338	−6,901	−9,216	−10,393
To prevent superficial SSI, 25%				
To prevent deep SSI, 0%	−3,277	−8,333	−9,813	−10,501
To prevent deep SSI, 5%	−4,440	−9,245	−10,616	−11,227
To prevent superficial SSI, 50%				
To prevent deep SSI, 0%	−8,410	−10,523	−11,442	−11,825
To prevent deep SSI, 5%	−8,539	−11,141	−11,776	−12,020

NOTE. Costs are presented in US dollars. Negative costs indicate cost savings. SSI, surgical site infection.

Triclosan-coated sutures continued to save costs per SSI prevented from the societal perspective, even if they prevented only superficial SSIs and not deep incisional SSIs. For surgeries having a 15% SSI risk, triclosan-coated sutures saved $35,116 (5% efficacious) to $48,684 (50% efficacious) per SSI prevented.

DISCUSSION

Our analyses show that even though triclosan-coated sutures are almost 40% more expensive than the traditional uncoated sutures ($9.93 vs $7.32/inch), the cost savings generated by preventing abdominal SSIs offset the extra suture costs, even when SSI risk is 15% and efficacy in preventing SSIs is as low as 5%. Depending on their efficacy, triclosan-coated sutures may, in fact, save more costs per SSI prevented than many other interventions. A study showed that collagen-gentamycin sponges for cardiothoracic surgeries save $84 per patient, preventing 45 surgical wound infections[45] and leading to $1,773 (2013 values) saved per SSI prevented. According to our model, triclosan-coated sutures, when used for abdominal surgeries with 15% SSI risk, saved approximately 2–8 times the costs per SSI prevented by collagen-gentamycin (hospital perspective). Also, as new technologies become available (eg, wound retractors[46] and antimicrobial abdominal meshes[47]), quantifying their potential cost-effectiveness becomes important, given the limited resources available for infection prevention and control. Hospitals may want to implement strategies that minimize costs while achieving a maximal reduction in SSIs. Head-to-head comparison of these multiple interventions in terms of costs and benefits will guide policy makers to determine the best strategy. Current recommendations may have to be reevaluated in light of the upcoming interventions to determine the most cost-effective strategies to prevent SSIs. Moreover, our results are not necessarily specific to triclosan, as other antimicrobials, such as silver, gentamycin, or neomycin, could be used for coating sutures.[48,49]

There are two systematic reviews regarding the efficacy of triclosan-coated sutures: one concluded that triclosan-coated sutures do not have a beneficial effect in preventing SSIs,[50] whereas the other demonstrated significant SSI reduction with triclosan-coated sutures.[51] These reviews include studies for colorectal, cardiac, breast, and shunt surgeries, which may have diverse SSI risks and risk factors. One review performed a subgroup analysis on abdominal procedures, showing that triclosan-coated sutures significantly reduce SSI risk by 31% (relative risk, 0.69 [95% confidence interval, 0.50–0.97]).[51] Among the studies evaluating abdominal procedures,[11-15,22] 2 showed no effect,[11,15] while others showed a substantial reduction in SSIs (35%–65%). The reasons for such a wide range in results are unclear and could be due to design limitations (small sample size and limited controls), varied incision closure methods, SSI definitions, incomplete data, or reporting biases.

Since the results from this analysis are sensitive to the efficacy of triclosan-coated sutures, additional studies are needed to establish the efficacy of such sutures and evaluate their benefits for surgeries with varied SSI rates. When evaluating the sutures, it is important to use standard SSI definitions, in order to allow comparisons across studies and gain more insight. Also, it will be beneficial if future studies incorporate details on SSI type; this would give a better handle on the cost and health benefits, if any, obtained by using triclosan-coated sutures. If sufficiently efficacious in preventing SSIs, triclosan-coated sutures can be cost-effective even when higher priced. The benefits obtained by using triclosan-coated sutures also depend on the SSI risk. Accurate quantification of SSI risk prior to surgery, using risk scores, may help stratify patients and consequently determine effective preventive strategies for various subgroups. The National Nosocomial Infections Surveillance risk score is commonly used, but it is often criticized for its discriminatory abilities and overly simplistic nature. Recently, there have been attempts to develop alternate indices to better predict SSI rates.[52,53] However, these must be further tested and validated.

One concern is that antimicrobial sutures may prevent only incisional SSIs and not organ space infections, which are associated with a higher morbidity, mortality, and costs.[54] However, a majority of SSIs are confined to incisions;[55] hence, interventions focusing on prevention of incisional SSIs could save substantial costs per SSI prevented, as reflected in our results ($40,127–$53,244/SSI prevented, societal perspective). Another concern is that the wide use of triclosan may lead to the development of antimicrobial resistance and thus decreased suture efficacy in preventing SSIs.[56] This is a very serious concern and suggests that efficacy numbers reported in the literature may not necessarily apply in the future. Also, in vitro studies suggest that triclosan use may further lead to the development of antibiotic resistance.[57,58] This highlights the need for more judicious and targeted use of triclosan, something that models such as ours can help guide.

It is important that policy makers consider the indirect costs along with the direct costs in order to be able to make an informed and well-rounded decision. Hospital and insurance databases typically do not capture productivity losses. When considering the societal perspective, the cost savings per surgery were 4–13 times those from the hospital or third-party payer perspectives. This shows that preventing productivity losses can save considerable costs per surgery, even when the SSIs are not associated with a high mortality rate (3.9% for superficial and 5.7% for deep incisional SSIs). Therefore, focusing on only the direct costs overlooks the impact of complicated cases that rapidly accrue costs.

Limitations. All models, by definition, are simplifications of real life,[59,60] and none can account for every possible SSI outcome. All data inputs for the model were obtained from sources of varied quality and rigor, including public databases, published literature, and expert opinion. We assumed that all pathogens had an equal probability of causing an SSI in clinical settings. Our model was conservative about the potential benefits of triclosan-coated sutures, considering their efficacy to be as low as 5%. It did not consider that some severe incisional SSIs may progress to organ space infections, incurring additional resources and costs. Also, for the societal perspective, our productivity loss calculations assumed a 40-hour work week and did not account for decreased productivity while recovering.

CONCLUSIONS

Our results show that triclosan-coated sutures save at least $4,000 per SSI prevented for hospitals and third-party payers and at least $23,500 per SSI prevented for society, if their efficacy is at least 10% and SSI risk is at least 10%. The high cost and risk of abdominal SSIs compensate for the cost premium of antimicrobial sutures, as long as the sutures have some efficacy in preventing SSIs. Future studies should better characterize this efficacy, but our study suggests that such sutures have the potential to save considerable costs.

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