Original Article

Cost-benefit analysis of craniocerebral surgical site infection control in tertiary hospitals in China

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Abstract

Introduction: Surgical site infection (SSI) is one of the most common postoperative complications. This study aimed to determine the cost of SSIs and to evaluate whether SSI control can reduce medical costs under the current medical payment system and wage rates in China.

Methodology: Prospective surveillance of craniocerebral surgery was conducted between July 2009 and June 2012. SSI patients and non-SSI patients were matched with a ratio of 1:2. Terms such as medical costs and length of hospital stay were compared between the two groups. Based on the economic loss of hospital infection, which causes additional expenditures and a reduction in the number of patients treated, the benefits of hospital infection control were estimated. The costs of human resources and materials of hospital infection surveillance and control were also estimated. Finally, the cost-benefit rates in different medical contexts and with different SSI-case ratios were calculated.

Results: The incidence of SSIs in this study was 4%. SSIs significantly prolonged hospital stay by 11.75 days (95% CI: 6.24–22.52), increased medical costs by US $3,412.48 (95% CI: $1,680.65–$5,879.89). The direct economic loss was $114,903 in a 40-bed ward. The cost of implementing infection control in such a unit was calculated to be approximately $5,555.47

Conclusions: Under the current fee-for-service healthcare model in China, the control of SSIs can hardly yield direct economic benefits, but can yield social benefits. With the implementation of a total medical cost pre-payment system, SSI control will present a remarkable benefit-cost ratio for hospitals.

Key words: craniocerebral operations; SSI; surveillance and control; cost-benefit analysis.

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Introduction

Surgical site infection (SSI) represents a significant portion of healthcare-associated infections, and has a higher incidence in certain procedures such as pancreatic surgery and colon surgery [1 - 3]. Current estimates of the yearly number of surgical procedures performed worldwide are over 234,000,000 (95% CI: 1.872–2.812) [4]. Additionally, more and more elderly people and those with underlying diseases and even impaired immune function are choosing to undergo surgeries. SSI is one of the most common postoperative complications [5,6] and is regarded as one of the most important medical safety concerns.

Medical costs and length of stay (LOS) increase in cases of SSIs [7,8]. The data released in 2009 by the United States Centers for Disease Control and Prevention (US CDD) shows that an SSI increased medical costs by $10,443–$20,842 [7]. The excess lengths of stay slightly vary depending on surgical sites, countries, time of surgery, and the methods of study. Based on all available literature, the excess lengths of stay for plastic surgeries and hip replacement due to SSIs are 28–32 days, longer than the 4 days for breast surgery patients [9,10].

SSIs pose a great threat to health; however, 26%–54% of these cases can be prevented [11]. In late 1970s, a study conducted by the US CDC demonstrated that in a six-year-long infection control program, SSI incidence decreased by 19%–41% due to infection control work performed by professionally trained infection control staff [12]. Since enormous manpower and resources are required to establish and maintain the proper operation of an infection control program to effectively reduce infection incidence, the associated benefit-cost ratio then becomes one of the most important factors that concern administrative health authorities and medical institutions. Medical economics evaluations conducted by European countries and the USA revealed that a very high benefit-cost ratio for infection control could be achieved [12,13]. However, China's social development level, medical payment system, and wage rates greatly differ from Western countries. Further investigation is needed to determine whether healthcare associated infection (HAI) control can bring good economic benefits.

Methodology

Economic losses resulting from nosocomial infections

A prospective surveillance of SSIs in craniocerebral operations was conducted between July 2009 and June 2012. In the surveillance, patients who developed craniocerebral SSIs and those who did not were matched in the ratio of 1:2 for type of operation, type of incision, American Society of Anesthesiology (ASA) score, sex, age ± 5 years, and date of operation ± 1 year. SSI was defined according to the surveillance definition by the Centers for Disease Control's National Healthcare Safety Network [14]. The major SSI types included meningitis or ventriculitis and intracranial infection. The patients with infection were selected as the case group, while the matched patients without infection were selected as the control group. Enrollment criteria for case group included patients with craniocerebral SSI (organ space infection, such as ventriculitis) and the appropriate matched case consistent with the criteria mentioned above. The exclusion criterion for the case group was existing infection(s) in other body parts before the occurrence of SSI. The enrollment criterion for the control group was no SSI of any kind (superficial incisional infection, deep incisional infection or organ space infection), and if there was more than one case matched to the case group, the two cases with the smallest age gap from the case group were chosen. If the two cases were of the same age, the one with the more recent operation date was selected. The exclusion criterion for the control group was preexisting infection at admission.

All kinds of medical costs, LOS, and incidence of a second operation were compared between the case and control groups to estimate economic losses per case of craniocerebral SSI. The annual decrease in patient volume due to infections was calculated by infection rate, volume of operations, and lengths of stay of the two groups.

Additional medical costs and the costs for the decrease in patient cases due to SSIs were considered to be economic losses from SSIs.

Costs for establishment and maintenance of infection control program in the hospital

Labor costs were calculated on the basis of staffing of infection control program by the CDC combined with the hospital's actual experience on nosocomial infections surveillance and control in recent years. An infection control team would have one full-time infection control staff, one part-time infection control nurse, and one infection control physician. Wage cost for each team member was calculated based on the proportion of their working time contributed to fulfilling their responsibilities of SSI surveillance and control.

Statistical methods

Statistical analysis was assessed by using SPSS version 18.0. Normally distributed measurement data were expressed as mean ± SD, while abnormally distributed measurement data were expressed as median or interquartile range. Paired *t*-test was used to check the normality, and two related samples test and nonparametric test (Wilcoxon test) were used for abnormal distribution measurement data. Chi-square test, continuous correction χ^2 test, or exact probability was used for enumeration data. $P < 0.05$ was considered to be statistically significant.

Results

Incidence of craniocerebral SSI and annual volumes of surgeries

Infection rate was 4% in the three-year long prospective study of patient data and active surveillance in the neurological surgery unit (40 beds). The annual volume of surgeries was calculated to be 800 cases on the basis of the surveillance data of this unit.

Case control study

In the surveillance over the last three years, 2,130 cases of craniocerebral surgeries were reviewed, of which 85 cases developed craniocerebral SSIs (organ space surgical site infection). Each patient with an SSI was matched to two patients who did not develop infections, consistent with the above-mentioned criteria, and on the basis of the matching principle defined in this study. Control cases were determined for 38 out of 85 cases with SSIs according to the matching criterion (matching ratio of 1:2). The 38 cases were enrolled as cases, and the 76 matched patients were included as controls. Among the 38 pairs, 16 (42.11%) had ASA scores of 1, and 22 (57.89%) had ASA scores of 2. No cases had ASA scores of 3, 4, or 5. Thirty-four pairs (89.47%) were type 1 incision and 4 (10.53%) were type 2 incision. In the case group, 16 (42.11%) were males and 22 (57.89%) were females. There was no significant difference (p = 0.562) between surgical cost (median, $8,598.01; interquartile range, $6,653.83–$11,426.99) for 38 patients enrolled with SSI and that (median, $8,146.43; interquartile range, $5,785.40–$12,090.28) for 47 excluded cases. These results suggest that the 38 infection patients enrolled with SSIs could be considered to be overall unbiased samples. The above-mentioned tests proved there was no significant difference in age, preoperative hospital stay, surgical costs, and anesthesia costs between the case and control groups. Detailed data are listed in Table 1.

Extended hospital stays due to SSIs

Median LOS for the case group was 29 days (interquartile range, 25.00–37.25) compared 17.25 days (interquartile range, 14.75–26.38) for the control group. The LOS for the infection group was 11.75 days (95% CI: 6.24–22.52) longer than that for the control group (p < 0.001, nonparametric Wilcoxon test).

Increased medical costs due to SSIs

The median overall medical cost for the case group was $8,598.01, $3,412.48 higher than that ($5,185.53) for the control group (p < 0.001).

In this study, hospitalization costs were broken down to further examine the composition of overall medical costs. Medication, materials, lab tests, treatment, examinations, and surgeries account for a relatively high proportion, over 90%, of the overall medical costs in both groups. In the control group, the biggest proportion was material costs (32.4%), followed by medication costs (20.7%) and surgical costs (14.2%), whereas in the case group, the biggest proportion was medication costs (37.3%), followed by material costs (24%), and lab tests (9.0%) other than surgeries. Statistical results indicated that costs for medication, materials, treatment, lab tests, imaging examinations, hospitalization, nursing care, and oxygen therapy for the case group were all significantly higher than for the control group aside from the significant difference in overall medical cost between the groups (Table 2).

Annual decrease in number of patients received

A decrease of 32 patients with craniocerebral operations was calculated based on 800 cases per year, an infection rate of 4%, annual excess LOS of 376 days due to SSIs, and LOS of 17.25 days per patient.

Direct economic losses due to SSI

SSIs have multiple consequences, such as increased suffering of patients and increased use of high-dose antibiotics leading to increased bacterial resistance. However, all of these cannot be calculated by an economic model. This study focused on the economic losses resulting from increased medical costs and decreased medical revenue due to fewer patients served by the departments.

The annual additional medical cost due to SSIs was $109,204 based on a craniocerebral SSI incidence of 4%, 40 beds, annual volumes of 800 surgeries, 32 craniocerebral operations, a mean medical cost of $8,598.01 for the case group with craniocerebral SSIs, a mean medical cost of $5,185.53 for the control group, and an additional medical cost of $3,412.48 for each SSI.

Decreased medical revenue resulted from decreased patient volume. As mentioned above, excess LOS of 11.75 days (95% CI: 6.24–22.52) for each patient, 40 beds, and annual volume of 800 cases was calculated to lead to a decrease of 22 patients served by the departments. The medical cost for these 22 patients was calculated to be $114,087 based on the mean medical cost of $5,185.53 for each patient in the control group. However, the proportion of hospital profit in the medical cost was difficult to calculate. According to the first national economic census data released by the State Statistics Bureau of China, the annual revenue for medical institutions across the country is 53.6 billion US dollars, with a surplus of 2.6 billion US dollars after the deduction of all costs and a surplus rate of 4.88%. Therefore, a profit loss of $5,704.08 due to the decrease in the number of patients was calculated by using a profit rate of 5% in this study. The combined losses amounted to $114,903.

Investment cost for SSI prevention and infection control program establishment

The cost for the infection control team consisting of a full-time infection control staff, a part-time infection control nurse, and a part-time infection control doctor was calculated as follows.

The full-time infection control staff would be responsible for designing surveillance methods and control schemes, supervising designing of tables and quality control throughout the surveillance process, diagnosing SSIs, and summarizing data.

Table 1. Basic data comparison between case and control groups

	Case group (n = 38)	Control group (n = 76)	P value
Age*	32.49 ± 15.03	32.93 ± 15.02	0.452
Preoperative stay**	10.5 (6.00–14.25)	7.25 (5.50–15.00)	0.330
Surgical costs**	4439.00 (US $2,632.75–$4,673.00)	4439.00 (US $2,958.48–$4,576.00)	0.644
Anesthesia costs**	415.00 (US $360.00–$539.00)	415.00 (US $360.00–$470.00)	0.149

*normal distributed data, expressed as mean ± standard deviation; **abnormal distribution data, expressed as median (interquartile range)

Table 2. Comparison of the break-down of hospitalization costs (USD) between case and control groups

	Case group (n = 38)	Control group (n = 76)	P value
Overall medical cost**	53,704.01 (41,560.44–71,374.08)	32,389.33 (21,694.73–41,837.55)	<0.001*
Medication cost**	17,963.64 (14,278.96–27,043.88)	5,888.40 (4,412.20–9,002.77)	<0.001*
Material cost**	13,996.85 (10,155.58–19,347.07)	10,985.47 (6,935.28–14,109.56)	0.009*
Surgical cost**	4,439.00 (2,632.75–4,673.00)	4,439.00 (2,958.48–4,576.00)	0.644
Treatment cost**	3,200.00 (1,022.02–4,684.15)	1,222.88 (793.88–2,441.54)	<0.001*
Lab test cost**	2,667.76 (2,128.00–4,358.38)	1,554.00 (1,041.25–2,475.25)	<0.001*
Imaging examination cost**	2,085.90 (1,186.41–3,010.66)	1,322.11 (963.84–1,919.71)	0.031*
Hospitalization cost**	929.00 (752.5–1,201.5)	574.00 (442.75–814.25)	<0.001*
Examination cost**	616.00 (48–10,134.00)	547.75 (278.88–8,365.38)	0.474
Anesthesia cost**	415.00 (360.00–539.00)	415.00 (360.00–470.00)	0.149
Nursing care cost**	326.50 (261.75–397.75)	214.25 (163.75–255.63)	<0.001*
Oxygen therapy cost**	250.25 (174.13–367.75)	199.50 (133.88–244.13)	0.012*

*$P < 0.05$; **abnormal distribution data, expressed as median (interquartile range)

Table 3. Benefit-cost estimate of conduction of infection control program (total medical cost pre-payment mode)

Proportion of decrease in infections	Post-infection decrease infection rate	Additional medical cost with expected infection rate (USD)	Economic losses due to decrease in patient size received with expected infection rate (USD)	Costs saved compared with baseline infection rate (benefits)	Cost of infection control program (USD)	Benefit-cost ratio
0 (baseline value)	4.0%	109,204	5,700	0	5,555	
5%	3.8%	103,745	5,363	5796	5,555	1.04
10%	3.6%	98,285	5,091	11,543	5,555	2.08
20%	3.2%	87,367	4,515	23,022	5,555	4.14
30%	2.8%	76,432	3,954	34,502	5,555	6.21
40%	2.4%	65,513	3,394	45,997	5,555	8.28
50%	2.0%	54,594	2,818	57,476	5,555	10.35
75%	1.0%	27,297	1,409	86,198	5,555	15.51
90%	0.4%	10,919	560	103,425	5,555	18.62

Table 4. Cost effect estimate of implementation of infection control program (current medical fee-for-service in China)

Proportion of decrease in infections	Post-decrease infection rate	Decrease in patient size with expected infection rate	Increase in patient size compared with baseline infection rate
0（baseline）	4.0%	22.00	
5%	3.8%	20.71	1.29
10%	3.6%	19.62	2.38
20%	3.2%	17.44	4.56
30%	2.8%	15.26	6.74
40%	2.4%	13.08	8.92
50%	2.0%	10.90	11.10
75%	1.0%	5.45	16.55
90%	0.4%	2.18	19.82

This person would have to contribute 1/7 of his full working time to fulfilling all these responsibilities. The annual labor cost would be $2,289.43 based on an annual salary of $16,010.

The part-time ward infection control nurse would be responsible for collecting and registering basic information of all surgical patients. This person would have to contribute 1/9 of her full working time to fulfilling all these responsibilities. The human cost would be $2,305.44 per year based on an annual salary of $20,813.

The infection control physician would be responsible for the diagnosis of intractable cases and for counseling. He would have to contribute 1/30 of his full working time to fulfilling all the responsibilities. The human cost would be $800.50 per year based on an annual salary of $24,015.

The resources and devices would include depreciation costs of computers and printers, office supplies, and electricity and water bills. The total cost was calculated to be $160.10 per year.

The total cost, therefore, would be approximately $5,555.47 per year to run an infection control program.

Cost-benefit analysis under different payment systems

The Chinese government is reforming its healthcare system and adapting payment methods that align with international standards. Healthcare providers have to cover on their own the economic losses of $114,903 due to nosocomial infections every year following the implementation of total medical cost pre-payment and disease-based payment systems. Infection control and reduction of SSI incidence can bring actual benefits by reducing additional medical costs and increasing the number of patients treated. The cost for implementing infection control in such a unit was calculated to be approximately $5,555.47.

Under such a payment mode, a medical cost of $5,555.47 could be saved due to decreased infection rate, and a profit of $336.21 could be made due to more patients being treated; if the number of patients with SSIs decreased by 5%, SSI incidence would decrease by 3.8%. In this case, a combined cost of $5,795.62 could be saved, which makes benefit and cost almost balanced (benefit-cost ratio 1.04). With the SSI incidence declining; the benefit-cost ratio would gradually increase. If one infection control program can reduce SSIs by 30%, medical costs of $34,501.55 could be saved for a unit, with the benefit-cost ratio reaching 6.21 (Table 3).

Currently, most medical institutions in China are still adapting fee-for-service payment; therefore, the additional cost resulting from nosocomial infections is covered by patients or medical insurance. Although the influence of nosocomial infections on a hospital's revenue is very limited, there are still a series of problems requiring solutions, such as bed turnover rate. As SSI rates decline, the number of patients treated increases (Table 4).

Discussion

SSI is one of the most common complications for surgical patients and is a major cause of increased medical costs and lengths of stay [1-3,5-6]. In this study, a strict case-control method was used to investigate the influence SSIs have on increasing medical costs and lengths of stay. The diagnostic and therapeutic costs and course of treatment for superficial incisional infection, deep incision infection, and organ space infection vary greatly, which is of significant difference [15]. The reliability and stability of the results of mixed analysis of three kinds of infection would be compromised due to the constituent ratio of the three kinds of infection. This study focused only on one kind of organ space infection in craniocerebral operations to minimize mixed factor effects. The results show that LOS was prolonged by 11.75 (95% CI: 6.24–22.52) days and that medical costs increased by $3,412.48 (95% CI: $1,680.65–$5,879.89) in cases of craniocerebral SSI. The annual economic losses combining increase in medical cost and decrease in number of patient treated due to SSIs amounted to $114,903 for a 40-bed unit.

SSIs pose a great threat to health; however, most of them are preventable [11]. According to literature published in recent years, the economic benefits of implementing an infection control program greatly outweigh its cost investment [13,16,17]. However, medical institutions in China do not take the economic losses from additional medical costs due to nosocomial infections because the losses have to be covered by patients or medical insurance under the Chinese traditional medical policy and payment mode, which are different from those of European countries and the USA. Although nosocomial infection control can bring benefits such as decreased use of antibiotics, increased patient turnover rate, and a harmonized relationship between doctors and patients, it cannot produce direct economic benefits. Economic benefits are the top priority for hospitals due to survival pressure. The mode of "cost only but no economic benefits" for infection control results in the fact that although national authorities have been tightening the supervision of infection control by rolling out all kinds of laws, regulations, and guidelines, they are not fully enforced at the grassroots level, leading to a lack of infection control programs in many small hospitals.

In recent years, as a healthcare reform is taking place in public hospitals in China, multiple payment modes, including pre-payment of total medical cost, disease-based payment, service-unit-based payment, and capitation to replace fee-for-service, have been introduced to strengthen medical insurance total payment control and to guide medical institutions to actively control cost, standardize diagnostic and treatment behavior, and improve service quality. Nosocomial infections will surely bring heavy economic burdens to medical institutions and related departments following implementation of pre-payment of total medical cost. Based on the data mentioned above in this study, each craniocerebral SSI will produce economic losses of $3,412.48 for the unit. According to an annual revenue surplus rate of approximately 5% for medical institutions released by the State Statistics Bureau, that means a gross earnings of $68,250.63 can offset the economic losses of only one SSI, which means the losses (hospitalization cost was estimated as $5,185.53 as in this study) of one SSI requires medical revenue from 13 surgical patients to offset it. It will produce no profit at all for medical institutions if the infection rate is > 13:1 (7.69%).

Considering the influence of the new payment system, it will be a totally different situation for the benefits generated by infection control. Under the new payment methods, the additional cost due to nosocomial infections will be covered by medical institutions. Apart from that, nosocomial infections also prolong LOS for patients, thus reducing the hospital's revenue due to a decrease in the number of patients treated. Based on the cost benefit of infection control calculated under these payment modes, the conclusion in this study shares great similarity with that of a study from the US CDC [12]: if SSI infection rate decreases by 5%, the cost saved is just sufficient to cover the cost of implementing an infection control program; if SSI infection rate decreases by 30%, the benefit-cost ratio is 6.21. In this study, due to the lack of a well-developed information system, all data were manually collected, which was time and effort consuming. With improvements in information technology in the future, such human costs are expected to decrease, with the possibility of yielding a favorable benefit-cost ratio of infection control programs.

There are, however, limitations in this study. One of these is that this was a single center study, which, although it can provide consistency and stability in data collection, suffers from insufficient representativeness. The cost was estimated in accordance with the wage level and commodity price in Beijing, which may be different from other regions. The surgeries investigated in this study were craniocerebral operations, which have been proven to have a higher incidence of infection and longer treatment duration [18,19]; postoperative meningitis and brain abscess antimicrobial duration usually last between at least three and four weeks, respectively, but only for two weeks for postoperative peritonitis. Therefore, the economic influences of SSIs with this study may be greater than other types of surgeries.

Conclusions

Under the current immature medical insurance mechanisms in China, SSI control can produce indirect benefits by increasing the bed turnover rate and harmonizing the relationship between doctors and patients; however, the costs still exceed anticipated benefits, which, to some extent, affects the implementation of infection control measures and fulfillment of infection control responsibilities by infection control professionals. In the future, should a total medical cost pre-payment system be implemented in China, SSI control would generate a very high benefit-cost ratio, which will not only make good infection control practice a vital foundation for hospitals to maintain healthy development, but would also maximize health safety, improve healthcare quality, and reallocate medical resources to benefit more patients.

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