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## Major Article

## Evaluating the direct economic burden of health care–associated infections among patients with colorectal cancer surgery in China

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## Key Words:

Colorectal cancer  
Health care–associated infections  
Economic burden**Background:** Little is known about the direct economic burden associated with health care–associated infection (HAI) in patients undergoing colorectal cancer surgery in China. This study aims to fill this knowledge gap.**Methods:** This study was a prospective monitoring case–control study. The direct economic burden was presented as the median of the 1:1 pair differences of various hospitalization fees and hospital length of stay. Wilcoxon signed-rank tests were used to explore the differences in the direct economic burden.**Results:** Out of 448 patients, 38 had acquired HAIs, with the infection incidence being 8.93%. The total direct economic burden of HAIs was \$1,589.30 ( $P < .05$ ). Among various infection sites, deep surgical site infection had the highest direct economic burden of \$8,654.44, followed by multisite infections (\$5,946.52). When it comes to various hospitalization costs, the cost for Western medicine (\$846.13) constituted the highest proportion of economic burden followed by treatment cost (\$145.73) and bed charge (\$126.75). On average, the length of hospital stay in the infection group was 6 days longer than that in the control group ( $P < .05$ ).**Conclusions:** HAI was associated with considerable economic burden for patients who underwent colorectal cancer surgery in China. The study highlights the necessity of taking effective measures to decrease incidence of HAIs to reduce economic burden.

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In the last few decades, the incidence and mortality of colorectal cancer, one of the most common cancers, show a rising trend in both China and worldwide.<sup>1,2</sup> Although the 5-year survival rate of early stage (stages I and II) colorectal cancer patients after surgery has reached 64.9%,<sup>3</sup> invasive examinations and surgery, radiation therapy, and chemotherapy will apparently impair the immunity of colorectal cancer patients and make them vulnerable to the development of health care–associated infections (HAIs). HAIs refer to all types of infections that patients acquire in hospitals, but the term excludes the infections which are in the incubation period on admission and occur after hospitalization.<sup>4</sup> Studies showed that colorectal surgery resulted in the highest rate of surgical site infection (SSI) among the major surgical categories partly because of the intestinal

bacterial translocation.<sup>5,6</sup> The occurrence of HAIs would contribute to an increase in the usage of medicine and an extension of chemotherapy intervals, hindering disease treatment and prognosis and increasing mortality.<sup>7</sup> Moreover, the constantly increasing costs of medicine, treatment, hospitalization, and chemotherapy at a rate greater than general inflation have caused an economic burden to patients' families and society.<sup>8,9</sup>

Furthermore, HAIs contribute to additional direct (health care related) economic burden to patients because of antibiotics usage, medical treatment, laboratory tests, and prolonged hospital length of stay (LOS). Studies about the economic burden of HAIs have been conducted in the United States, the United Kingdom, France, India, Japan, and Taiwan.<sup>5,10–14</sup> A U.S. study found that the economic burden was \$22,272 per patient associated with HAIs.<sup>15</sup> Another study in France pointed out that HAIs prolonged hospital LOS 3-fold.<sup>12</sup> Additionally, it is estimated that SSIs extended hospital LOS by 9.7 days while increasing medical cost by \$20,842 per admission on average in the United States.<sup>5</sup> Likewise, the economic burden of HAIs has shown to be high in China among patients with acute leukemia.<sup>16</sup> Although the economic burden of HAIs per annum in China is unclear, these HAIs will undoubtedly impose a substantial economic

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burden on the national health care system, given the large population size of China.

HAI has become a highly concerned issue in today's medical community, especially in developing countries such as China.<sup>17</sup> The overcrowded in-hospital environment, insufficient disinfection equipment and disinfectants, and the shortage of medical staff will inevitably contribute to the occurrence of HAIs. However, studies on the economic burden of HAIs among patients who underwent colorectal cancer surgery in China are currently lacking. Given the high prevalence and severity of HAIs, this research aims to offer clear evidence for the direct economic burden that can be caused by HAIs, therefore promote hospitals and authorities to prevent HAIs and save medical expenses among colorectal cancer patients undergoing surgery.

## METHODS

### *Study setting and participants*

This study was conducted in a tertiary public hospital at Shandong province, which was ranked as the first 25% in economy development among provinces and municipalities in China. The per capita disposable annual income of residents in Shandong province was \$3,405.45 in 2015. Approximately 93% of the population in Shandong province have national basic medical insurance, which can cover about 60% of total in-hospital expenses among colorectal cancer patients. The hospital is capable of accommodating >4,500 inpatients and caters for 3.27 million outpatients every year. The general surgery wards, with >170 beds, are able to provide surgeries for >300 colorectal cancer patients every year.

All colorectal cancer patients who were admitted to the general surgery wards from January 1-December 31, 2015, were eligible. The inclusion criteria included the following: (1) patients aged  $\geq 18$  years; (2) patients diagnosed with colorectal cancer through histopathology examination; (3) patients who had undergone surgical removal of tumors; and (4) patients who had undergone first-stage resection, anastomosis operation, and expanded or joint resection (eg, expanded pelvic organ resection, joint liver or pancreatic or stomach or intestinal resection). On the other hand, patients who were undergoing palliative surgery, transanal rectal surgery, or Hartmann operation (this procedure applies to emergency surgery or is used in palliative patients) were excluded. This is because Hartmann operation involves the formation of a stoma, where extra cost, which is unrelated to HAIs, will be incurred to these patients. Furthermore, patients undergoing palliative surgery are likely to exhibit severe comorbidities, and transanal rectal surgery removes rectal tumors through the anus, which does not involve abdominal incisions. Those patients undergoing transanal rectal surgery would recover faster and cost less than patients treated with abdominal incisions. For these reasons, these patients were excluded from the study.

### *Process of matching*

We estimated the economic burden of HAIs by comparing the all-cause hospitalization costs between patients with and without HAIs using a 1:1 matching sample. The matched method aims to estimate incremental hospitalization costs and hospital LOS among patients with versus without HAIs who had similar demographic characteristics at baseline. According to a previous study, factors related to hospitalization expenses include age, sex, preoperative comorbidity, and postoperative complications.<sup>18</sup> Therefore, in our study, we adopted a matching method of the same sex, similar age ( $\pm 10$  years), and same disease diagnosis. We also matched the sub-

jects based on whether they had accompanied comorbidity, adopted laparoscopy, and received multiple surgeries.

### *HAI surveillance and definition*

During the study, a consistently prospective target monitoring of HAIs was conducted through the hospital infection surveillance system. It is a locally suitable infection surveillance system which can monitor and detect suspected HAIs through emerged signs or symptoms (eg, fever, high white blood cells count). Upper respiratory tract infection, lower respiratory tract infection or pneumonia, SSI, and multisite infection were assessed in our study. The diagnoses of these infections were made according to the patient's clinical presentation and results of laboratory tests, radiographs, computerized tomography scans, endoscopic examinations, and other tests, combined with the HAI standards promulgated by the Centers for Disease Control and Prevention.<sup>4</sup> Doctors or health professionals specializing in infections made the final diagnoses of HAIs. Only those infections which occurred after 48 hours of hospital admission were considered as HAIs because this indicated that the infections were neither incubating nor acquired before the patients were admitted to hospital.

### *Data collection*

The hospital infection surveillance system and the hospital information system were searched by 2 independent researchers to collect the required data of patients. Most hospital wards can accommodate multiple people. All patients after surgery will be monitored in a separate multiperson room for about 1 day before being transferred to normal wards. All patients are under standard precaution of hospital infections with strategies including washing hands and wearing gloves, gowns, and masks by medical staff. In the case of suspected infections or bacterial resistance, bacterial culture or isolation in single rooms will be implemented to prevent the spread of infections. On average, colorectal cancer surgeries take place on 6.7 days after admission in the targeted hospital. Information on patients' demographic characteristics, diagnosis, hospitalization costs, and hospital LOS was obtained from the hospital information system, whereas characteristics of HAIs were retrieved from the hospital infection surveillance system using an author-developed information sheet. The incremental total hospitalization costs and hospital LOS associated with HAIs were the primary outcomes, whereas the increment of various hospital fees associated with HAIs and total hospitalization costs for different infection sites were the secondary outcomes. In our study, Western medicine mainly consists of chemotherapeutic drugs and antibiotics. Treatment cost include the medical care provided to patients and charges of the required medical equipment and supplies. Health materials mainly involve surgical supplies and surgical incision package. Examination expenses are costs of health examinations, such as radiograph and computerized tomography scan. The research protocol was approved by the Ethics Committee of the Qilu Hospital of Shandong University, and we remained strictly confidential of the collected data.

### *Statistical analysis*

Demographic data are presented as mean  $\pm$  SD or number (%). Differences within the categorical variables such as marital status and diagnosis were analyzed using the  $\chi^2$  test, whereas those within the continuous variables of baseline characteristics were evaluated using *t* tests. As for hospitalization costs, we used the Wilcoxon signed-rank tests to explore the cost differences between infection and control groups. The infection incidence was calculated by

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