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Original Research

Geographical outcome disparities in infection occurrence after colorectal surgery: An analysis of 58,096 colorectal surgical procedures

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HIGHLIGHTS

- There is no spatial analysis of surgical site infection across the communities.
- Geographical variation and clustering in colorectal surgical site infection exist.
- Homogeneity in surgical site infection pattern in urban areas compared to rural areas.
- Significant high-high and low-low clusters was observed in NSW, in Australia.

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ABSTRACT

Background: Despite improved surgical practices and in-hospital surveillance systems, surgical site infections remain a major public health problem worldwide and often require readmission to hospital. The aim was to apply an advance and innovative spatial analysis approach to identify spatial pattern and clustering (hotspots) of surgical site infection rate (CSIR), and quantifying disparities across communities.
Methods: We used the Admitted Patient Data Collection for patients aged 18 years and over who underwent colorectal surgery in a public hospital between 2002 and 2013 in the Australian State of New South Wales (NSW). The colorectal surgical infection rate (CSIR) was computed. We assessed geographical variation and clustering in CSIR patterning to demonstrate spatial pattern and clustering across communities in NSW, Australia.
Results: There were 58,096 colorectal surgical procedures conducted in NSW from 2002 to 2013. The overall occurrence of CSIR was 9.64% (95%CI 9.40–9.88%). We found significant clusters of both high and low CSIR in outer regional and remote areas of NSW.
Conclusion: Use of advanced spatial analyses allows identification of hotspots/clusters of adverse events that can help policy makers and clinicians better understand national patterns and initiate research to address disparities/geographical variation, and clustering of adverse events after surgery.

1. Introduction

Despite improved surgical practices and in-hospital surveillance systems, surgical site infections remain a major public health problem worldwide and often require readmission to hospital [1–3]. Among hospitalised patients, one in 25 will have an infection and more than 20% of these infections can be attributed to surgery [4,5]. Strikingly, one in ten infected patients will die as a result. Large, unexplained variations exist in mortality after surgical complications (i.e. surgical site infection) in colorectal cancer (CRC) across geographic areas. The potential exists for quality improvement efforts targeted at census-tract levels to prevent complications such as infection [6]. One way to address this is via application of spatial analyses to surgical site infection and includes both

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exploratory and confirmatory spatial analysis of surgical site infection prevalence, mortality and survival in local populations.

Through the quantification of spatial patterns, hotspots and outliers can be identified and changes in pattern can be analysed over time and space. The purpose of this research was to assess geographical variation and clustering in CSIR patterning by applying a two-step geographic analysis approach to demonstrate spatial pattern and clustering (hotspots) of surgical infection prevalence rates across communities in New South Wales, Australia.

2. Methods

We used the Admitted Patient Data Collection [7] for patients aged 18 years and over who underwent colorectal surgery in a public hospital between 1st January 2002 and 31st December 2013 in the Australian State of New South Wales (NSW). Infection following a surgical procedure (ICD-10-AM T81.4) was extracted for colorectal surgeries (i.e. incision, resection or anastomosis of the large intestine). The study was approved by the Ethics Review Committee.

For each patient's residence postcode, we calculated the total number of infected cases and the total number of patients who underwent a colorectal surgery in public and private hospitals in NSW. The colorectal surgical infection rate (CSIR) was computed as the number of infected cases divided by the number of patients who underwent a colorectal surgery.

The Local Moran's I statistic, as a common spatial cluster detection method is a good way to identify local spatial clusters of postcode level CSIR. The local Moran's I statistics of spatial association is given by Ref. [8];

$$I_i = \frac{z_i - \overline{z}}{\sigma^2} \sum_{j=1,\ j \neq i}^{n} \left[W_{ij} (z_j - \overline{z}) \right],$$

where $\overline{z}$ is the mean value of z (CSIR) with the postcode number of n; z_i is the value of the CSIR at the postcode location i; z_j is the CSIR value at other locations (where $j \neq i$); σ^2 is the variance of z (CSIR); and W_{ij} is a distance weighting between z_i and z_j, which can be defined as the inverse of the distance. The weight W_{ij} can also be determined using a distance band: postcodes within a distance band are given the same weight, while those outside the distance band are given the weight of 0. The spatial weights matrix for colorectal surgical infection rate for each postcode were defined using an inverse distance method in which neighbouring postcodes' colorectal surgical infection rate have a larger influence on the weights computations for a target postcode than postcodes that are far away. By applying this methods, spatial weights diminishes with distance.

The Anselin Local Moran's I (spatial statistics) algorithm generates a local Moran's I value, a Z score, a p-value, and a code representing the cluster type [8,9]. It identifies hotspots (high-high), coldspots (low-low), and spatial outliers (high-low and low-high). A positive Local Moran's I value indicates that the target postcode is surrounded by postcodes with similar rates (high-high: postcode with a high CSIR rate surrounded by postcodes with high rates; low-low: postcode with a low CSIR rate surrounded by postcodes with low rates). A negative Local Moran's I value indicates that the target postcode is surrounded by postcodes with dissimilar rates (high-low: postcode with a high rate surrounded by postcodes with low rates; low-high: postcode with a low rate surrounded by postcodes with high CSIR rates). The designation of postcodes to these four classes depends on the results of a statistical test. This test performs random comparisons among the target postcodes Moran's I value and its neighbouring postcodes values to all postcodes' Moran's I values within the study area, and compares the observed Moran's I value to the value corresponding to the random permutations (expected Moran's I value). If the test is significant ($p \leq 0.05$), the observed Moran's I value is significantly larger (or smaller in the case of a negative relationship) than the expected Moran's I value. If the test is not significant, the postcode remains in a neutral class (no spatial dependence).

3. Results

There were 58,096 colorectal surgical procedures conducted in NSW from 2002 to 2013. The overall occurrence of colorectal surgical site infection was 9.64% (95%CI 9.40–9.88%). The majority of patients (87%) with colorectal surgical infection living in hotspots areas underwent surgery in medium- or high-volume hospitals and only 13% of surgeries were performed at low-volume institutions.

A thematic map was used to examine the spatial patterns of CSIR in NSW communities (Fig. 1). A thematic map can visually demonstrate the geographical pattern and distribution of one or more specific data themes for selected spatial units. To ensure the confidentiality of patients, postcodes with less than five patients were excluded from the analysis. This thematic map revealed a great deal of spatial variation in CSIR across postcodes in NSW. The Local Moran's I statistic, as aforementioned, was used to identify local spatial clusters of CSIR at the postcode level in NSW. Statistically significant high-high, low-low, and outlier local clusters were visualised using a map with postcodes boundaries in NSW (Fig. 2).

A great deal of variation of CSIR in NSW was evident in the typical analyses undertaken as shown in Fig. 1. However, the results from the local Moran I analysis revealed many more specific clusters and outliers of CSIR (Fig. 2). Almost all significant clusters of colorectal surgical infection appeared to be in outer regional and remote areas of NSW. The low-low clusters of CSIR were observed in metropolitan areas such as Sydney.

4. Discussion

Using the described methods, we identified a great deal of spatial variation in the patterns of CSIR across NSW communities. The local Moran I analyses revealed significant clusters/hotspots of both high and low CSIR located in outer regional and remote areas of NSW that might not be easily recognised using typical spatial analyses (i.e. thematic maps). This suggests that disparity in outcomes should be first addressed in outer regional and remote areas and interventions (i.e. post-surgical care in the community) should focus on patients from remote areas. The geographical patterns were not explained by hospital volume. There is evidence of more homogeneity among communities in urban built-up areas compared with those in outer regional and remote areas of NSW.

Use of advanced spatial analyses allows identification of hotspots/clusters of adverse events that can help policy makers and clinicians better understand national patterns and initiate research to address disparities/geographical variation, and clustering of adverse events after surgery. These innovative analyses can be conducted internationally for a number of important short-term and long-term clinical endpoints after major surgical procedures.

Spatial variation in the CSIR patterns suggests that a single one size fits all intervention strategy would be unlikely to efficiently or effectively improve surgery outcomes in communities. The approach taken in this research supports the design and development of efficient community-level health intervention strategies by identifying communities with the highest potential impact and allowing for the prioritisation of prevention interventions to be