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Original article

Quantifying the improvement in sepsis diagnosis, documentation, and coding: the marginal causal effect of year of hospitalization on sepsis diagnosis

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ABSTRACT

Purpose: To quantify the coinciding improvement in the clinical diagnosis of sepsis, its documentation in the electronic health records, and subsequent medical coding of sepsis for billing purposes in recent years.
Methods: We examined 98,267 hospitalizations in 66,208 patients who met systemic inflammatory response syndrome criteria at a tertiary care center from 2008 to 2012. We used g-computation to estimate the causal effect of the year of hospitalization on receiving an *International Classification of Diseases, Ninth Revision, Clinical Modification* discharge diagnosis code for sepsis by estimating changes in the probability of getting diagnosed and coded for sepsis during the study period.
Results: When adjusted for demographics, Charlson-Deyo comorbidity index, blood culture frequency per hospitalization, and intensive care unit admission, the causal risk difference for receiving a discharge code for sepsis per 100 hospitalizations with systemic inflammatory response syndrome, had the hospitalization occurred in 2012, was estimated to be 3.9% (95% confidence interval [CI], 3.8%–4.0%), 3.4% (95% CI, 3.3%–3.5%), 2.2% (95% CI, 2.1%–2.3%), and 0.9% (95% CI, 0.8%–1.1%) from 2008 to 2011, respectively.
Conclusions: Patients with similar characteristics and risk factors had a higher of probability of getting diagnosed, documented, and coded for sepsis in 2012 than in previous years, which contributed to an apparent increase in sepsis incidence.

Sepsis, the dysregulated systemic inflammatory response to a severe infection, is a leading cause of death in the United States [1]. The Agency for Healthcare Research and Quality reported sepsis as the most expensive and the sixth most common principal reason for hospitalization in the United States with an economic burden of $15.4 billion in 2009 [2]. Several studies have reported an increase in hospitalizations for sepsis in recent years [3–11]. Data from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project indicated a 32% increase in the rate of sepsis hospitalizations from 492 per 100,000 population in 2005 to 651 per 100,000 population in 2010 [11].

Several hypotheses have been proposed to explain the factors contributing to the apparent increase in sepsis incidence. Some studies have suggested that changes in population characteristics, such as increases in age and higher burden of comorbidities in hospitalized patients, have contributed to the apparent increase in sepsis incidence [4,5,10]. Although the true incidence of sepsis could be increasing, the apparent increase may, at least in part, be due to improvements in the clinical diagnosis of sepsis in health care settings. The clinical diagnosis of sepsis relies on the documented or probable presence of infection in addition to systemic manifestations of the infectious process, commonly referred to as the systemic inflammatory response syndrome (SIRS). Although diagnostic testing has remained largely unchanged in the last decade with respect to sepsis diagnosis, the importance of early recognition and treatment has received much attention through national campaigns to reduce mortality [12]. Additionally,

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increased access to emergency medical services and hospitals and utilization of intensive care services may have improved the capacity to clinically diagnose sepsis [12,13]. Better documentation of sepsis in the electronic health record by clinicians and an increase in medical coding of sepsis for billing purposes may have also contributed to an apparent increase in sepsis incidence in studies that rely on administrative data to estimate temporal trends [3–11].

To the best of our knowledge, given the multiple factors that may impact sepsis incidence, there has not been a study quantifying the potential coinciding improvement in sepsis diagnosis and documentation and the corresponding coding for an individual patient that may have contributed to increased sepsis incidence in recent years. In this study, we adapted the counterfactual causal inference framework [14,15] to assess this coinciding improvement in the "diagnosis of sepsis" by estimating the changes in the probability of the "diagnosis of sepsis" in patients with similar characteristics and risk factors in recent years.

Methods

Study design and population

We conducted a retrospective cohort study of patients with the SIRS at Barnes-Jewish Hospital (BJH), a 1250-bed academic tertiary care referral center in St Louis, MO. BJH is affiliated with the Washington University School of Medicine and has more than 50,000 inpatient admissions annually. Patient-level clinical and administrative data from BJH were obtained from the BJC Center for Clinical Excellence medical informatics data repository.

Eligible participants included all patients (aged $\geq$18 years) who were admitted to BJH between January 1, 2008 and December 31, 2012 and met SIRS criteria regardless of their discharge status or death. A patient was defined as having SIRS when at least two of four of the following criteria were present on a given calendar day: heart rate of above 90 beats per minute; respiratory rate above 20 breaths per minute; body temperature less than 36°C or above 38.3°C; and white blood cell count less than 4000 cells per microliter or above 12,000 cells per microliter [16]. To minimize transient changes in heart rate, respiratory rate, and temperature, patients had to have at least two out of range measurements on a given calendar day for these to be considered as meeting SIRS criteria; however, a single out of range white blood cell count on a given calendar day was counted toward the SIRS criteria. Thus, the study population included patients with one or more hospitalizations, during which a singleday or multiday episode of SIRS was recorded. Hospitalizations where patients did not meet the SIRS criteria were not included.

The study was approved by the Human Research Protection Office of the Washington University School of Medicine with a waiver of written informed consent.

Description of data

The primary outcome of interest included having a discharge diagnosis code for sepsis during hospitalizations with an episode of SIRS. Discharge diagnoses are assigned by medical coders, based on patients' medical records (charts), for billing purposes upon discharge or death. A discharge diagnosis of sepsis was defined by the presence of *International Classification of Diseases, Ninth Revision, Clinical Modification* discharge diagnosis codes of 995.91 (sepsis), 995.92 (severe sepsis), or 785.52 (septic shock) as a principal or secondary diagnosis. Demographics, vital sign measurements (heart rate, respiratory rate, and temperature), laboratory tests (white blood cell count), and hospital discharge diagnoses were obtained from the BJC medical informatics data repository, which houses administrative data and electronic health records. The covariates included age, sex, race, Charlson-Deyo comorbidity index [17], number of blood cultures drawn during the hospitalization, the length of hospitalization, admission or transfer to an intensive care unit (ICU), and the year of hospitalization (as a categorical variable). The year of hospitalization was considered to be a population-level covariate and a proxy for improved "diagnosis of sepsis".

Analytic approach

Our primary hypothesis for this study was that among patients with similar risk factors and baseline characteristics, the year of hospitalization will not have a significant effect on the probability of "developing" sepsis. We assessed whether the probability of having a discharge diagnosis of sepsis among patients with similar covariates, who had a similar probability of developing sepsis, changed between 2008 and 2012. The parametric g-computation method was used to estimate the marginal causal effect of the year of hospitalization on the probability of having a "diagnosis of sepsis" [18,19].

First, a mixed-effects logistic regression [20] was used to model the log-odds of having a discharge diagnosis of sepsis on the covariates. Mixed-effect models allow explicit modeling of correlations among observed outcomes because of repeated hospitalizations for some patients. Nested models were compared by the likelihood ratio test with regard to both the fixed and random effects. All models included random effects for patients to account for the possibility that some patients had multiple hospitalizations with SIRS. Other random effects considered were the year and month of SIRS hospitalizations.

Second, using the final model from the first step, the probability of each patient's outcome was estimated using his and/or her observed covariates. Moreover, using the final model, the probabilities of potential outcomes, referred to as counterfactual outcomes, for each patient were estimated by setting the year of hospitalization to a year other than the observed year. This allowed us to estimate the probabilities of potential (i.e., counterfactual) outcomes occurring had a patient, contrary to fact, been hospitalized in another year, under identical circumstances with regard to their baseline covariates and risk factors.

Third, using the entire generated sets of probabilities of the counterfactual outcomes for each patient from the second step, the marginal causal effect (causal risk difference) of the year of hospitalization was estimated by fitting a marginal structural model of the probability of a diagnosis of sepsis on the year of hospitalization to determine the expected change in the probability of occurrence of the outcomes of patients, had they been hospitalized in a year other than their true hospitalization year [19]. The residual sampling bootstrap method [21] was used to estimate the standard errors and construct the confidence intervals for the parameters of the marginal structural model, that is, the marginal effect of the year of hospitalization.

Finally, the absolute increase in the number of sepsis diagnoses during 2008 to 2011, compared to 2012, was calculated by multiplying the number of SIRS hospitalizations in each year between 2008 and 2011 by the corresponding estimate of the causal risk difference. Model fitting and computations were done using "lme4" library [22] in the R software 3.1.1 [23].

Results

The characteristics of the study population are listed in Table 1. A total of 98,267 (of 273,266 total; 36.0%) hospitalizations with oneday or multiday episodes of SIRS in 66,208 (of 150,559 total; 44.0%) patients were included in the cohort. There were 16,056