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Do Robotic Surgical Systems Improve Profit Margins? A Cross-Sectional Analysis of California Hospitals

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ABSTRACT

Background: The aim of this study was to examine the association between ownership of robotic surgical systems and hospital profit margins. **Methods:** This study used hospital annual utilization data, annual financial data, and discharge data for year 2011 from the California Office of Statewide Health Planning and Development. We first performed bivariate analysis to compare mean profit margin by hospital and market characteristics and to examine whether these characteristics differed between hospitals that had one or more robotic surgical systems in 2011 and those that did not. We applied the *t* test and the F test to compare mean profit margin between two groups and among three or more groups, respectively. We then conducted multilevel logistic regression to determine the association between ownership of robotic surgical systems and having a positive profit margin after controlling for other hospital and market characteristics and accounting for possible correlation among hospitals located within the same market. **Results:** The study sample included 167 California hospitals with valid financial information. Hospitals with robotic surgical systems tended to report more favorable profit margins. However, multilevel logistic regression showed that this relationship (an association, not causality) became only marginally significant (odds ratio [OR] = 6.2; P = 0.053) after controlling for other hospital characteristics, such as ownership type, teaching status, bed size, and surgical volumes, and market characteristics, such as total number of robotic surgical systems owned by other hospitals in the same market area. **Conclusions:** As robotic surgical systems become widely disseminated, hospital decision makers should carefully evaluate the financial and clinical implications before making a capital investment in this technology.

Keywords: hospital finance, hospital profit margin, hysterectomy, prostatectomy, robotic surgery, technology diffusion.

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Introduction

Robot-assisted surgeries have become increasingly popular worldwide. The number of robot-assisted procedures performed in the United States has skyrocketed from 80,000 in 2007 to 205,000 in 2009 [1]. During that same period, the number of US hospitals that acquired robotic surgical systems increased from 800 to 1400 [1]and further expanded to over 2500 in 2016 [2]. As of late 2015, clinical applications of robotic surgical systems have encompassed a wide range of surgical procedures, including urologic surgery (e.g., prostatectomy, partial nephrectomy), gynecology (e.g., hysterectomy, sacrocolpopexy), general surgery (e.g., colorectal surgery, hernia repair, cholecystectomy, bariatric surgery), cardiothoracic surgery (e.g., mitral valve repair, thoracic surgery), and head and neck surgery (e.g., transoral surgery) [3]. One study estimated that completely replacing conventional surgeries with robotic ones would increase health care costs by more than $2.5 billion annually—even without considering the possible increases in surgery volumes [1]. The proliferation of robotic surgical systems has raised concerns that it marks the latest "medical arms race" in the US health care system [4].

The acquisition of a robotic surgical system is a major capital investment for hospitals. The price of a da Vinci system is $1.5 million to $2.5 million, with an annual service fee ranging from $100,000 to $170,000. In addition, the system's single-use instruments and accessories cost an additional $700 to $3200 per procedure [2]. Clinical and business considerations drive the embracement of this new technology by hospitals. Clinically, robotic surgical systems make it easier to perform laparoscopic procedures. Despite this new technology's potential for lessening the technical complexities of operations, studies comparing the surgical outcomes between robot-assisted surgeries and open surgeries or between robot-assisted surgeries and laparoscopic procedures not robot-assisted have been mixed [5–7]. In the business sense, consumers may perceive the ownership of new technologies, such as robotic surgical systems, as a signal of a cutting-edge, high-quality institution, thus attracting more patients [8]. Owning a robotic surgical system may also help recruit surgeons, who then bring their patients to that hospital.

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Despite the continuing expansion in the number of robotic surgical systems in the United States, the financial impact of this acquisition on US hospitals remains unclear. The objective of this study was to examine the association between ownership of robotic surgical systems and hospital profit margins.

Methods

We used data from the State of California Office of Statewide Health Planning and Development (OSHPD) for 2011 to explore our research question. We chose California hospitals because information on both purchase dates and financial performance for these hospitals was available. Specifically, Section 127285 (3) of the Health and Safety Code requires hospitals to report acquisitions of diagnostic or therapeutic equipment with a value in excess of $500,000 [9]. In 2002, the OSHPD added a section on major capital expenditures to its Hospital Annual Utilization Data and required hospitals to include a written description of such equipment, its cost, and date of acquisition. These reporting requirements allowed us to identify hospitals that had purchased robotic surgical systems and the corresponding date of purchase. The OSHPD Annual Financial Data provides information on hospital characteristics and operating revenue and expenses; profit margin was calculated as (operating revenue − operating expense) / operating revenue [10]. We excluded short-term and long-term psychiatric hospitals and those without operating rooms because such hospitals are unlikely to purchase robotic surgical systems. We calculated surgical volumes for each hospital by linking the aforementioned hospital-level files to hospital discharge data via unique facility identifiers. To determine the market area for each hospital, we mapped the address of each hospital to the corresponding hospital service area (HSA) using the zip code–HSA crosswalk from the Dartmouth Atlas [11]. The study was exempted by the institutional review board at the lead author's institution because of the use of deidentified data.

In addition to the binary variable indicating the ownership of at least one robotic surgical system (yes or no), we constructed a list of variables to capture hospital and market characteristics. Hospital characteristics included institutional characteristics and practice characteristics. Institutional characteristics of hospitals were quantified as hospital's ownership type (for-profit, not-for-profit, or government), teaching status (yes or no), and bed size (categorized as <175, 176–350, and >350 beds), whereas practice characteristics of hospitals were measured by relevant surgical volumes and case mix index. As the application of robot-assisted procedures had been focused mostly on prostatectomies and hysterectomies around 2011, we defined relevant surgical volume as the total count of these two surgical procedures [12]. We calculated the relevant surgical volume by linking the hospital financial data to hospital discharge data. We used the International Classification of Diseases, ninth edition (ICD-9) procedure codes to identify prostatectomy (60.2, 60.3, 60.4, 60.5, 60.6) and hysterectomy (68.3, 68.4, 68.5, 68.6, 68.7, 68.9) and classified hospitals by the combined surgical volumes of these two procedures and trichotomized hospitals into high-, medium-, and low-volume hospitals (>256, 74–256, and <74). The case mix index reflects the diversity, clinical complexity, and resource needs of the hospital patient population. The indexes were obtained from the case mix index file that reports the case mix OSHPD calculated for each hospital based on Medicare Severity-Diagnosis Related Groups and their associated weights [13]. Market characteristics were captured by the total number of robotic surgical systems owned by other hospitals in the same HSA.

We performed bivariate analysis to compare mean profit margin by hospital and market characteristics and to examine whether these characteristics differed between hospitals that had one or more robotic surgical systems in 2011 and those that did not. We applied the t test and the F test to compare mean profit margin between two groups and among three or more groups, respectively, and used the chi-square test to determine whether robotic ownership differed by hospital characteristics. Next, we conducted multilevel logistic regression to determine the association between ownership of robotic surgical systems and having a positive profit margin, after controlling for other hospital and market characteristics and accounting for possible correlation among hospitals located within the same market (i.e., HSA) [14].

All statistical analyses were conducted using STATA (version 13; StataCorp, College Station, TX). Statistical significance was defined as having a P value less than 0.05.

Results

Using our selection criteria, we identified 167 California hospitals for analysis. Among them, 45 (27%) owned one or more robotic surgical systems, and 117 (70%) reported a positive profit margin. Among the hospitals with one or more robotic surgical systems, approximately 89% (40 of 45) reported a positive profit margin in 2011 compared with 64% (77 of 122) of hospitals with operation rooms but without a robotic surgical system. Table 1 (second column) compares the mean profit margin by hospital characteristics. Higher profit margins were observed in the following type of hospitals: hospitals that owned robotic surgical systems, were nongovernmental, and had high surgical volumes. Columns 3 to 5 in Table 1 compare the hospital and market characteristics by ownership status of robotic surgical systems. Hospitals with robotic surgical systems tended to be nonprofit teaching hospitals, and hospitals that had large bed sizes, high surgical volumes, and higher case mix indices.

Results from four specifications of multilevel logistic regressions are summarized in Table 2. To explore how various types of covariates affected the association between ownership of robotic surgical systems and having a positive profit margin, we started with an unadjusted model (Model I), then sequentially added hospital institutional factors (Model II), all variables of hospital characteristics (Model III), and hospital plus market characteristics (full model, Model IV). For each model specification, the use of multilevel models that considered the nested structure of hospitals within market areas, instead of one-level models, was supported by the likelihood ratio tests. The unadjusted model showed that hospitals with robotic surgical systems were 5.6 times ($P = 0.002$) more likely to report positive profit margins than those without robotic systems. However, the OR was gradually reduced as we controlled for more covariates and eventually became only marginally significant (OR = 3.60; $P = 0.053$) in the full model. In addition, a significantly positive association was found in high surgical volume (vs low-volume) hospitals (OR = 6.2; $P = 0.013$), whereas a significantly negative association was found in government (vs for-profit) hospitals (OR = 0.11; $P = 0.007$). No statistically significant association was observed between profit margins and market characteristics, quantified by the total number of robotic surgical systems available in other hospitals within the same market area.

Discussion

Using cross-sectional data from hospitals in California, this study explored the association between ownership of robotic surgical systems and hospital profit margins. The data suggest that although California hospitals with robotic surgical systems in 2011 tended to report more favorable profit margins, this

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