Surgical Oncology 22 (2013) 178–183

Contents lists available at SciVerse ScienceDirect

Surgical Oncology

journal homepage: www.elsevier.com/locate/suronc

Review

# Breast cancer surgery volume-cost associations: Hierarchical linear regression and propensity score matching analysis in a nationwide Taiwan population

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ARTICLE INFO

*Article history:*
Accepted 28 May 2013

*Keywords:*
Breast cancer surgery
Volume
Cost
Taiwan

ABSTRACT

*Background:* No outcome studies have longitudinally and systematically compared the effects of hospital and surgeon volume on breast cancer surgery costs in an Asian population. This study purposed to evaluate the use of hospital and surgeon volume for predicting breast cancer surgery costs.
*Methods:* This cohort study retrospectively analyzed 97,215 breast cancer surgeries performed from 1996 to 2010. Relationships between volumes and costs were analyzed by propensity score matching and by hierarchical linear regression.
*Results:* The mean breast cancer surgery costs for all breast cancer surgeries performed during the study period was $1485.3 dollars. The average breast cancer surgery costs for high-volume hospitals and surgeons were 12% and 26% lower, respectively, than those for low-volume hospitals and surgeons. Propensity score matching analysis showed that the average breast cancer surgery costs for breast cancer surgery procedures performed by high-volume hospitals ($1428.6 dollars) significantly differed from the average breast cancer surgery costs of those performed by low-/medium-volume hospitals ($1514.0 dollars) and that the average breast cancer surgery costs of procedures performed by high-volume surgeons ($1359.0 dollars) significantly differed from the average breast cancer surgery costs of those performed by low-/medium-volume surgeons ($1550.3 dollars) ($P < 0.001$).
*Conclusions:* The factors significantly associated with hospital resource utilization for this procedure included age, surgical type, Charlson co-morbidity index score, hospital type, hospital volume, and surgeon volume. The data indicate that analyzing and emulating the treatment strategies used by high-volume hospitals and by high-volume surgeons may reduce overall breast cancer surgery costs.


**Contents**



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http://dx.doi.org/10.1016/j.suronc.2013.05.004

## Introduction

Luft and his colleagues identified multiple dimensions of the complex relationship in their award winning study in which they raised the question of whether volume was indeed the source of the superior outcomes identified, or whether selective referral patterns to highly proficient practitioners and facilities might be the source of the relationship [1,2]. As a result, some controversy has continued concerning the strength of the volume outcome relationship in the health services research community.

Although convincing evidence suggests that high hospital volume and high surgeon volume contribute to favorable outcomes, no studies have specifically measured the effects of high hospital and surgeon volume in terms of hospital treatment cost [3–5]. Additionally, no studies have attempted to quantify the reproducibility of health care practices that tend to obtain favorable outcomes. Finally, despite the strong evidence of volume-outcome relationships observed in studies of specific surgical procedures, few studies of the association have exceeded ten years, and most published data are for US or European populations [3–5]. Until now, no longitudinal comparisons of breast cancer surgery outcomes among varying hospital/surgeon volumes and no systematic comparisons of breast cancer surgery outcomes have been performed in a Taiwan population.

This study therefore performed hierarchical linear regression and propensity score matching to test hospital/surgeon volume for associations with breast cancer surgery costs. The models were constructed using population-based data to minimize the effect of selection bias.

## Patients and methods

### *Patients and study design*

This study analyzed administrative claims data obtained from the Taiwan Bureau of National Health Insurance (BNHI). As the BNHI consists of de-identified secondary data released to the public for research purposes, after consulting with the director of the Institutional Review Board (IRB), this study was waived from review and approved by the Kaohsiung Medical University IRB.

Each discharge record contained up to 15 of the diagnostic codes and up to 15 of the procedure codes listed in the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM). These codes were used to identify the surgery type as well as the indications for surgery. Initially, 109,060 breast cancer patients were eligible for recruitment for the study. Patients were excluded if they had not received curative surgery ($N = 11{,}250$), if they had received more than two surgical procedures after their first diagnosis of breast cancer ($N = 186$), and if their records did not indicate the date of surgery ($N = 19$). Patients whose records indicated that they had been younger than 18 years on the date of surgery were also excluded ($N = 390$). The final study sample included 97,215 patients who had received breast cancer surgery between January 1, 1996, and December 31, 2010.

### *Potential confounders*

The analyzed patient attributes included age, surgical procedure type and co-morbidities. Surgical procedure type was classified as breast conserving surgery (BCS), modified radical mastectomy (MRM), or mastectomy with reconstruction (TRAM). The ICD-9-CM codes for primary and secondary diagnoses were used to identify co-morbidities and to calculate Deyo-Charlson co-morbidity index (CCI) scores [6]. The analyzed hospital attributes were hospital type, hospital volume, and surgeon volume. The hospitals/surgeons included in the database were sorted by total patient volume, and each was assigned a unique identification code. In accordance with outcome-volume studies performed earlier by the authors, hospitals that had performed 1–34, 35–59 and ≧60 breast cancer surgery procedures annually during the study period were classified as low-, medium- and high-volume hospitals, respectively, and surgeons who had performed 1–10, 11–17 and ≧18 breast cancer surgery procedures annually were classified as low-, medium- and high-volume surgeons, respectively [6,7]. This was evaluated annually for each surgeon and hospital so that, for instance, the same surgeon could be classified as medium volume in one year and high volume the next.

### *Statistical analysis*

The unit of analysis in this study was the individual breast cancer patient. Regarding breast cancer surgery costs, the data analysis included costs in the standard administrative claims data required by the Taiwan BNHI: operating room, radiology, physical therapy, hospital room, anesthetist, pharmacy, laboratory, special materials, surgeon, and others. Breast cancer surgery cost was adjusted for different hospital levels according to their differences in BNHI reimbursements. To reflect changes in real dollar value, cost data were also adjusted by the consumer price index for each year of 1996–2010.

The hierarchical linear regression model was used to analyze associations with breast cancer surgery costs in the different volume groups and in the reference group after adjusting for these confounders. Additionally, hierarchical linear regression method was used to minimize the potential hospital clustering effect, i.e., to minimize the effect of policies, procedures, or surgeon compensation mechanisms unique to a hospital on in the care quality data and cost data [8,9].

As suggested by Rosenbaum and Rubin, propensity analysis was performed to minimize the effect of selection bias on the study hypothesis [10,11]. Propensity scores in this observational study were stratified by replacing the potential covariates with variables. The propensity scores were calculated by entering the attributes of the patients and the attributes of the hospitals in this study into a