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ORIGINAL ARTICLE

Association between perioperative oral care and postoperative pneumonia after cancer resection: conventional versus high-dimensional propensity score matching analysis

Miho Ishimaru[1] · Sachiko Ono[2] · Hiroki Matsui[1] · Hideo Yasunaga[1]

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Abstract

Objectives Perioperative oral care was reported to decrease postoperative pneumonia after cancer resections. However, the effect remains controversial because previous studies were limited due to their small sample sizes and lack of strict control for patient backgrounds. The present study evaluated the association between perioperative oral care and postoperative pneumonia using high-dimensional propensity score (hd-PS) matching to adjust for confounding factors.

Materials and methods Using a Japanese health insurance claims database, we identified patients who underwent surgical treatment of cancer from April 2014 to March 2015. To compare outcomes (postoperative pneumonia and procedure-related complications) between patients with and without perioperative oral care, we performed hd-PS matching and conventional PS matching and chi-square test.

Results We identified 621 patients with oral care and 4374 patients without oral care. The occurrences of postoperative pneumonia were not significantly different between patients with and without oral care in the unmatched (2.9% vs. 3.2%), conventional PS-matched (2.9% vs. 2.9%), or hd-PS-matched (2.9% vs. 3.3%) groups. The occurrences of procedure-related complication were not significantly different between patients with and without oral care in the unmatched (23.8% vs. 24.5%), conventional PS-matched (23.8% vs. 26.4%), or hd-PS-matched (24.4% vs. 27.7%) groups.

Conclusions There was no significant difference in postoperative pneumonia or procedure-related complications between patients with and without perioperative oral care.

Clinical relevance While maintaining optimal oral care in cancer patients is an important goal, the present study revealed no significant difference in postoperative outcomes. Further investigations would be needed to determine the effect of perioperative oral care.

Keywords Oral hygiene · Perioperative care · Postoperative complications · Propensity score analysis

Introduction

Oral care has been reported to be an effective approach to decrease pneumonia. Several systematic reviews and meta-analyses showed oral care including chlorhexidine use significantly decreased mechanically ventilator-associated pneumonia [1–4]. Furthermore, routine oral care for elderly residents in nursing home was reported to prevent nursing home-acquired pneumonia [5–7]. Oral care can improve poor oral condition, severe periodontal disease, and dental plaque, which is associated with increase in pathogens colonizing in oral cavity [8, 9]. For intubated patients and elderly residents in nursing home, pathogens in saliva can easily leak into trachea and may cause lung infection [10, 11].

Perioperative oral care was also likely to decrease postoperative pneumonia after head and neck cancer resection, esophageal cancer resection, and lung cancer resection [12–17]. Postoperative pneumonia is one of the most common fatal complications after cancer resections. The incidence rates of postoperative pneumonia were reported to 7.3–38% of

✉ Miho Ishimaru
miho-ishimaru@umin.ac.jp

[1] Department of Clinical Epidemiology and Health Economics, School of Public Health, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

[2] Department of Biostatistics & Bioinformatics, The University of Tokyo, Tokyo, Japan

patients after esophagectomy [18, 19], and 3.5% of patients after several major cancer surgeries [20]. Postoperative pneumonia significantly increased morbidity, mortality, length of hospital stay, and treatment costs [1]. Several studies have investigated the association between perioperative oral care and postoperative pneumonia; however, these studies were limited due to their small sample sizes and lack of strict control for patient backgrounds [13–22].

In the present study, we evaluated the effect of perioperative oral care by dental providers to prevent postoperative pneumonia in several types of cancer patients, using a Japanese administrative claims database. We performed high-dimensional propensity score (hd-PS) matching and conventional PS matching analyses for balancing patient backgrounds and adjusting confounding factors.

Methods

Data source

This study was performed using a health insurance claims database developed by the Japan Medical Data Centre Co. Ltd. (Tokyo, Japan). The details of the database have been described elsewhere [23, 24]. As of 2015, the database included outpatient and inpatient health insurance claims of approximately 1.6 million patients, which accounted for about 1.3% of the entire Japanese population. The data consisted of encrypted unique identifiers, age, and sex, diagnoses coded according to the International Classification of Diseases, 10th Revision (ICD-10) codes; and medications and procedures coded according to Japanese original codes. The database also included data on body mass index, smoking status, and alcohol consumption. The Institutional Review Board at The University of Tokyo approved the study protocol. Informed consent was waived because of the anonymous nature of the data.

Patients

We identified patients who underwent resection of the following types of cancer from April 2014 to March 2015: head and neck, lung, gastric, colorectal, breast, and esophageal cancer. We excluded patients who were first enrolled in the database within 365 days before the day of admission. When patients underwent two or more cancer resections, the first surgery was included in our analysis. Patients who had undergone perioperative oral care by dentists were identified using Japanese original procedure codes. Perioperative oral care was defined as a reimbursement when surgeons for each cancer treatment requested dentists to provide oral care before cancer resections.

Outcomes

The primary outcomes of the present study were postoperative pneumonia (ICD-10 codes J12-J18, J69, and J84) and procedure-related complications (T81).

Hd-PS estimation

Hd-PS analysis has been proposed as an approach to improve the ability to control for confounding factors in comparative effectiveness studies using administrative claims databases [25–28]. We performed hd-PS matching between patients with and without perioperative oral care. The detailed methods for hd-PS estimation were reported in a previous study [26]. Briefly, the following five steps were implemented: (1) identification of different data dimensions, (2) identification of hundreds of the most prevalent codes in each data dimension as candidate covariates during the preoperative period, (3) assessment of candidate covariates with their frequencies, (4) ranking of candidate covariates across all dimensions by their potential of confounding factors based on Bross's formula [29], and (5) selection of the top of *n* highest potential covariates for PS modeling.

In the present study, the preoperative period was defined as the period within 365 days before the day of admission. We structured the following five dimensions: outpatient diagnoses, inpatient diagnoses, outpatient procedures, inpatient procedures, and outpatient and inpatient drug use. We included the top of 500 highest potential covariates in the logistic regression model for receiving perioperative oral care to estimate the hd-PS. We also included the following covariates in the model: age (≤ 50, 51–60, and > 60 years), sex, cancer site, type of hospital (academic or nonacademic), and annual hospital volume (average number of patients in each hospital who underwent perioperative oral care per year). The annual hospital volume was categorized into low-volume (< 12 cases per year) and high-volume (≥ 12 cases per year) groups to ensure almost equal numbers of patients in the two categories.

Conventional PS estimation

We included demographic factors and hospital factors in a logistic regression model for receiving oral care to estimate conventional PS. Demographic factors included age, sex, type of cancer resection, and disease history during the preoperative period. Disease history included hypertension (ICD 10 codes I10 or I15), diabetes mellitus (E10–E14), ischemic heart disease (I20–I25), heart failure (I50), renal failure (N17–N19), chronic obstructive pulmonary disease (J44), asthma (J45), pneumonia (J12–J18, J69, J84, and J95.8), and cerebrovascular disease (I60–I69). Hospital factors included the type of hospital and annual hospital volume.

PS matching and absolute standardized differences

We performed one-to-one and nearest-neighbor matching with 0.20 times the standard deviations of the logit of the PS as a caliper value without replacement.

To test the ability to balance the distribution of covariates between patients with and without oral care, we calculated the absolute standardized differences for 21 categories of 6 covariates included in the PS estimation: 3 categories of age (≤ 50, 51–60, and > 60 years), 1 category of sex (female), 6 categories of cancer site (head and neck, esophagus, lung, stomach, colon and rectum, and breast), 1 category of hospital type (academic hospital), 1 category of annual hospital volume (≥ 12 cases per year), and 9 categories of disease history (hypertension, diabetes mellitus, ischemic heart disease, heart failure, renal failure, chronic obstructive pulmonary disease, asthma, pneumonia, and cerebrovascular diseases).

We also calculated the absolute standardized differences for 10 categories of 3 variables that were not included in the PS estimation: 4 categories of body mass index (< 18.5, 18.5–24.9, and ≥ 25.0 kg/m^2 and missing data), 3 categories of smoking status (ex- or current smoker, nonsmoker, and missing data), and three categories of alcohol consumption (drinker, nondrinker, and missing data). These variables may be confounding factors, but we could not include them in the PS estimation models because there were too many missing values.

An absolute standardized difference of > 0.1 was defined as out of balance. The proportions of the outcomes were compared using the chi-square test between patients with and without perioperative oral care. The threshold for significance was a p value of ≤ 0.05. All analyses were performed using R version 3.1.2. (R Foundation for Statistical Computing, Vienna, Austria).

Statistical power analysis

We conducted a priori sample size estimation. Following a previous study [30], we set the prevalence proportions of postoperative pneumonia after cancer resection in the control group and the perioperative oral care group at 25% and 15%, respectively. Alpha and beta errors were set 0.05 and 0.80, respectively.

Results

We determined the optimal sample size to detect the effect difference was 250 cases per group. We identified 4995 eligible patients. These patients were categorized into those with oral care ($n = 621$) and without oral care ($n = 4374$). We generated 618 pairs by conventional PS matching. We also generated 581 pairs for postoperative pneumonia and 574 pairs for procedure-related complications by hd-PS matching (Fig. 1).

Table 1 shows the patients' baseline characteristics that were included in the PS estimation model for the unmatched group, conventional PS-matched group, hd-PS-matched group for postoperative pneumonia, and hd-PS-matched group for procedure-related complications. Patients were more likely to receive perioperative oral care if they had the following characteristics: older age, non-academic hospital, larger hospital volume, head and neck cancer, esophageal cancer, gastric cancer, non-lung cancer, non-breast cancer, hypertension, diabetes mellitus, and cerebrovascular disease. The number of categories with an absolute standardized difference of > 0.1 was 12 in the unmatched group, 1 in the conventional PS-matched group, and 0 in the hd-PS-matched group.

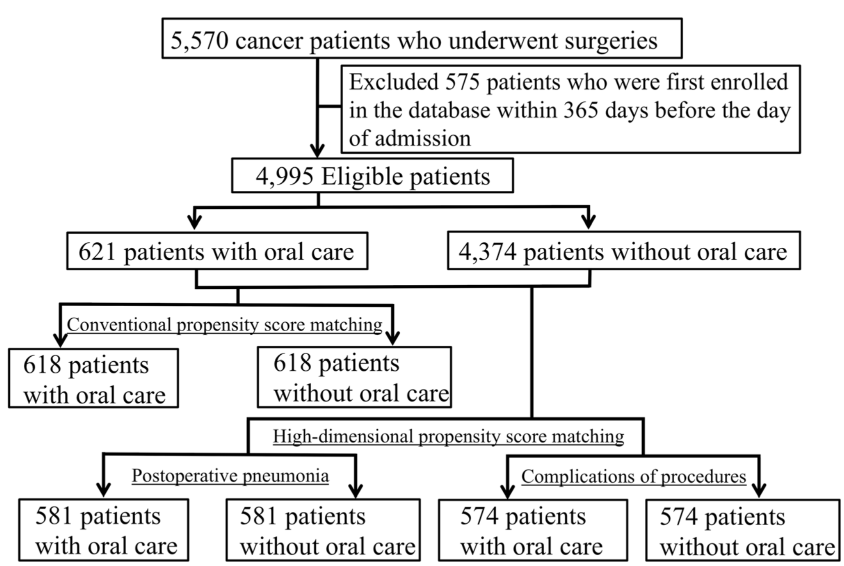

Fig. 1 Eligible patients undergoing conventional propensity-score matching and high-dimensional propensity score matching

Table 1 Distribution of patient backgrounds included in the PS estimation model in patients with and without oral care in the unmatched, conventional PS-matched, and hd-PS-matched groups

	Unmatched			Conventional PS-matched			hd-PS-matched for postoperative pneumonia			hd-PS-matched for procedure-related complications		
	With oral care, % ($n = 621$	Without oral care, % ($n = 4374$)	ASD	With oral care, % ($n = 618$)	Without oral care, % ($n = 618$)	ASD	With oral care, % ($n = 581$)	Without oral care, % ($n = 581$)	ASD	With oral care, % ($n = 574$)	Without oral care,% ($n = 574$)	ASD
Age (years)												
≤ 50	30.0	48.9	*0.395*	29.8	30.1	0.007	31.0	31.2	0.004	31.5	31.5	0.000
51–60	37.7	29.3	*0.179*	37.5	39.3	0.037	36.8	36.8	0.000	37.5	37.8	0.007
≥ 61	32.4	21.9	*0.238*	32.2	30.1	0.045	32.2	32.0	0.004	31.0	30.7	0.008
Sex, female	50.6	47.3	0.066	50.2	47.2	0.062	49.1	50.9	0.038	48.8	51.6	0.056
Academic hospital	14.2	18.9	*0.127*	14.0	12.2	0.053	14.3	15.5	0.034	13.8	16.0	0.064
Hospital volume ≥ 12 cases/year	61.5	18.9	*0.265*	62.2	58.5	0.076	60.9	61.4	0.011	61.3	61.7	0.007
Cancer site												
Head and neck	2.4	1.8	0.046	2.4	2.6	0.010	2.2	2.6	0.022	2.4	3.1	0.042
Esophagus	4.2	1.3	*0.177*	3.9	3.5	0.017	3.1	3.4	0.019	3.3	3.5	0.010
Lung	19.0	28.5	*0.224*	19.2	15.1	*0.107*	19.1	20.1	0.026	19.3	20.4	0.026
Stomach	19.5	9.8	*0.276*	19.3	19.8	0.012	20.8	20.8	0.000	18.8	18.1	0.018
Colon and rectum	27.5	23.5	0.092	27.2	29.6	0.054	26.7	27.9	0.027	26.7	27.5	0.020
Breast	27.4	35.1	*0.167*	27.4	28.8	0.032	28.9	28.1	0.019	29.4	27.4	0.046
Disease history												
Hypertension	30.1	22.0	0.185	30.1	31.2	0.025	29.8	28.6	0.027	28.7	26.1	0.059
Diabetes mellitus	58.6	47.0	*0.235*	58.3	57.5	0.016	58.0	58.7	0.014	57.1	60.1	0.060
Renal failure	1.3	1.8	0.044	1.3	1.3	0.000	1.2	2.4	0.091	1.4	1.7	0.028
Ischemic heart disease	20.6	18.8	0.045	20.5	20.8	0.008	19.6	22.7	0.076	19.9	22.5	0.064
Chronic heart failure	15.9	14.6	0.038	15.8	14.5	0.036	15.8	14.5	0.038	14.8	16.4	0.043
Pneumonia	13.7	13.1	0.018	13.7	11.4	0.068	13.9	14.6	0.020	13.8	14.8	0.030
COPD	4.5	3.1	0.073	4.5	3.7	0.041	4.5	3.4	0.053	4.0	3.3	0.037
Asthma	10.0	12.5	0.081	10.0	7.2	0.098	10.2	10.8	0.022	9.9	11.8	0.062
Cerebrovascular disease	9.8	7.0	*0.101*	9.8	8.7	0.039	9.6	7.2	0.087	8.7	8.7	0.000

PS, propensity score; *hd-PS*, high-dimensional propensity score; *ASD*, absolute standardized difference; *COPD*, chronic obstructive pulmonary disease

Each ASD of > 0.1 is shown in italic

Table 2 Distribution of variables not included in the PS estimation model in patients with and without oral care in the unmatched, conventional PS-matched, and hd-PS-matched groups

	Unmatched			Conventional PS-matched			hd-PS-matched for postoperative pneumonia			hd-PS-matched for procedure-related complications		
	With oral care, % (n = 621)	Without oral care, % (n = 4374)	ASD	With oral care, % (n = 618)	Without oral care, % (n = 618)	ASD	With oral care, % (n = 581)	Without oral care, % (n = 581)	ASD	With oral care, % (n = 574)	Without oral care,% (n = 574)	ASD
Body mass index (kg/m^2)												
< 18.5	7.2	6.7	0.020	7.1	5.2	0.081	7.2	5.0	0.094	7.0	5.2	0.073
18.5–24.9	54.4	44.5	*0.199*	54.1	51.0	0.062	54.6	54.7	0.003	54.2	52.4	0.035
≥25.0	14.5	12.2	0.067	14.5	15.3	0.023	13.9	13.8	0.005	14.6	14.5	0.005
Missing data	23.1	36.5	0.279	23.8	28.0	0.096	24.3	26.5	0.051	24.2	27.9	0.083
Smoking												
Current or ex-smoker	21.3	14.7	*0.171*	21.1	19.6	0.036	21.0	19.8	0.030	20.4	20.0	0.009
Nonsmoker	53.0	47.3	*0.114*	52.7	50.2	0.049	52.7	52.3	0.007	53.8	49.8	0.080
Missing data	25.8	38.0	*0.265*	25.8	29.6	0.087	26.3	27.9	0.035	25.8	30.1	0.097
Alcohol consumption												
Drinker	41.1	32.1	*0.186*	40.7	36.9	0.080	40.4	40.3	0.004	40.4	38.2	0.046
Nondrinker	30.4	26.1	0.096	30.3	29.0	0.028	30.8	28.2	0.057	31.0	29.8	0.027
Missing data	28.5	41.5	*0.275*	28.5	33.7	*0.112*	28.7	31.5	0.060	28.6	32.1	0.076

PS, propensity score; *hd-PS*, high-dimensional propensity score; *ASD*, absolute standardized difference. Each ASD of > 0.1 is shown in italic

Table 2 shows the distribution of the variables that were not included in the PS estimation model. The number of categories with an absolute standardized difference of > 0.1 was 7 in the unmatched group, 1 in the conventional PS-matched group, and 0 in the hd-PS-matched group. In the conventional PS matched groups, the absolute values of the standardized difference were < 10% for all baseline characteristics.

Table 3 presents the proportions of postoperative pneumonia and procedure-related complications. The proportions of postoperative pneumonia did not differ significantly between patients with and without oral care in the unmatched (2.9% vs. 3.2%), conventional PS-matched (2.9% vs. 2.9%), or hd-PS-matched (2.9% vs. 3.3%) groups. The proportions of procedure-related complication did not differ significantly between patients with and without oral care in the unmatched (23.8% vs. 24.5%), conventional PS-matched (23.8%% vs. 26.4%), or hd-PS-matched (24.4% vs. 27.7%) groups.

Discussion

The present study showed that there was no significant difference in postoperative pneumonia or procedure-related complications between patients with and without perioperative oral care using hd-PS matched analysis and conventional PS matched analysis.

The proportion of postoperative pneumonia in our study was lower than those in previous studies. There are two considerable reasons. First, our database did not include patients older than 75 years, but a previous study showed significant association between age and postoperative pneumonia [20]. Second, our study included relatively high numbers of patients with gastric, breast, and colorectal cancer resections, whereas the numbers of patients with esophagectomy and head and neck cancer resections were small. Reportedly, these two surgeries were associated with higher frequency of postoperative pneumonia [31–33].

The proportions of procedure-related complication were reported to 21–63.6% in head and neck cancer resection [21, 22]. Previous studies reported that perioperative oral care reduced the risk of postoperative surgical site infection [21]. However, data were lacking on the relationship between perioperative oral care and procedure-related complication. In the present study, procedure-related complications were likely to be lower in the perioperative oral care group than the control group, although not statistically significant.

Unmeasured confounders generally exist in observational studies, particularly in administrative claim data studies. Several methods for controlling unmeasured confounders have been developed to date. Hd-PS-matched analysis was reported to have several advanced points compared with conventional PS-matched analysis. First, hd-PS matching has been shown to balance patient backgrounds better than did

Table 3 Proportions of patients with postoperative pneumonia and procedure-related complications

		Postoperative pneumonia		Procedure-related complications	
		With oral care	Without oral care	With oral care	Without oral care
Unmatched group	*n*	621	4374	621	4374
	Event	18	139	148	1070
	Proportion (%)	2.9	3.2	23.8	24.5
	Risk difference (%), (95% CI)	− 0.3 (− 1.7 to 1.1)		− 0.7 (− 4.2 to 3.0)	
	p	0.80		0.77	
Conventional PS-matched group	*n*	618	618	618	618
	Event	18	18	147	163
	Proportion (%)	2.9	2.9	23.8	26.4
	Risk difference (%), (95% CI)	0.0 (not available)		− 2.6 (− 7.4 to 2.2)	
	p	1.00		0.33	
hd-PS-matched group	*n*	581	581	574	574
	Event	17	19	140	159
	Proportion (%)	2.9	3.3	24.4	27.7
	Risk difference (%), (95% CI)	− 0.3 (− 2.3 to 1.7)		− 3.3 (− 8.4 to 1.8)	
	p	0.87		0.23	

PS, propensity score; *hd-PS*, high-dimensional propensity score; *CI*, confidence interval

conventional PS in empirical settings [28, 34–40]. Performance of PS matching should be assessed with respect to its ability to balance the backgrounds of the patient groups being compared [36]. Second, an hd-PS algorithm has the potential to control unmeasured confounders with adjustment for thousands of covariates [36], whereas conventional PS-matched analysis only adjusts for factors included in the PS estimation model. We used hd-PS-matched analysis and conventional PS-matched analysis to adjust for confounding factors. The results in the hd-PS-matched analysis showed a similar trend to those in the conventional analysis.

To the best of our knowledge, this paper was the first study that evaluated the association between perioperative oral care and postoperative pneumonia with control of biases using hd-PS-matched method. Furthermore, our study has the largest sample size of any to have examined the association between perioperative oral care and postoperative pneumonia [12–17].

The present study had several limitations. First, recorded diagnoses are generally less well validated in administrative data. Regarding Japanese claims databases, a previous validation study showed that recorded diagnoses had high specificity but lower sensitivity, while recorded medications and procedures had high sensitivity and specificity [41]. Second, we had no data on several potential confounders, including each patient's dental services and dental conditions. Third, the small sample size precluded us from performing subset analyses for different types of cancer. However, for example, patients with head and neck cancer may have different responses to perioperative oral care, compared with patients with colorectal cancer. Fourth, the sample size in the present study may have been underpowered to judge the effect. Contrary to prior expectation, we obtained a relatively small difference in postoperative pneumonia—only 0.4%—in the hd-PS-matched groups.

Conclusion

While maintaining optimal oral care in cancer patients is an important goal, the present study showed no significant difference in postoperative pneumonia or procedure-related complications between patients with and without perioperative oral care.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The Institutional Review Board at The University of Tokyo approved the study protocol.

Informed consent Informed consent was waived because of the anonymous nature of the data.

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