pay, was smaller in Japan compared with other OECD countries, which also supported the notion that the impact of catastrophic copayment was rather limited in Japan. Despite this system, our results showed unequal utilization in favor of the rich. Catastrophic copayment would be more likely to happen in inpatient service use, although our data did not discriminate outpatient and inpatient services. Because the rate of inpatient service use was far smaller than that of outpatient service use, what this study found is mainly applicable to the latter. Further investigation, specifically of the horizontal inequity in inpatient service use is required in future.

Finally, we relied on household income to obtain relative ranks of household ability to pay, although income may not be a good indicator especially among retired individuals (Allin, Masseria, & Mossialos, 2009). Household expenditure for non-food consumption is recommended as the best indicator of household ability to pay, although reliable data are currently not available in Japanese surveys of household and health status. Again, it is imperative to collect nationwide survey data on household consumption and detailed information on healthcare utilization so as to precisely assess the performance of the healthcare system in Japan.

Conclusion

Despite the above limitations, our results strongly suggest the existence of widening inequality in access to healthcare in favor of the rich in Japan since the 2000s. This was mainly caused by declining health status among poor people aged 20–64 years, and increasing attribution of household income to the propensity for healthcare utilization. Although the Japanese health insurance system has achieved a relatively high degree of horizontal equity by global standards, our results provide the lesson that universal coverage of healthcare does not necessarily guarantee access equity, and changing economic and demographic conditions affect the degree of equity. To achieve horizontal equity in healthcare access, universal insurance, although important, is yet only one element; achievement of horizontal equity through universal coverage is not a goal but an ongoing project that requires continuous redesign of contribution and benefit in Japan's healthcare system.

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Health benefits of reduced patient cost sharing in Japan

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Objective To assess the effect on out-of-pocket medical spending and physical and mental health of Japan's reduction in health-care cost sharing from 30% to 10% when people turn 70 years of age.

Methods Study data came from a 2007 nationally-representative cross-sectional survey of 10 293 adults aged 64 to 75 years. Physical health was assessed using a 16-point scale based on self-reported data on general health, mobility, self-care, activities of daily living and pain. Mental health was assessed using a 24-point scale based on the Kessler-6 instrument for nonspecific psychological distress. The effect of reduced cost sharing was estimated using a regression discontinuity design.

Findings For adults aged 70 to 75 years whose income made them ineligible for reduced cost sharing, neither out-of-pocket spending nor health outcomes differed from the values expected on the basis of the trend observed in 64- to 69-year-olds. However, for eligible adults aged 70 to 75 years, out-of-pocket spending was significantly lower ($P < 0.001$) and mental health was significantly better ($P < 0.001$) than expected. These differences emerged abruptly at the age of 70 years. Moreover, the mental health benefits were similar in individuals who were and were not using health-care services ($P = 0.502$ for interaction). The improvement in physical health after the age of 70 years in adults eligible for reduced cost-sharing tended to be greater than in non-eligible adults ($P = 0.084$).

Conclusion Reduced cost sharing was associated with lower out-of-pocket medical spending and improved mental health in older Japanese adults.

Abstracts in عربي, 中文, Français, Русский and Español at the end of each article.

Introduction

Asking patients to share the cost of health care is a measure frequently used to reduce demand and control the health-care budget.[1–5] Moreover, patient cost sharing can also help finance universal health-care systems by raising additional revenue.[6] However, there is still some debate about the level of cost sharing that is best able to control costs while ensuring access to health care, preventing impoverishment from out-of-pocket spending and avoiding adverse health effects.[7,8] Several studies have quantified the effects of health insurance coverage and cost sharing on the use of important health services, but few have investigated their influence on health outcomes.[9–14] Most studies were conducted in the United States of America, where universal insurance coverage has not been achieved.[9,11,12,15–20] The extent to which health outcomes are influenced by cost sharing under national health insurance programmes in other countries is unclear. In this study, we assessed how health outcomes in elderly adults were affected by a change in cost sharing under the universal national health insurance programme in Japan.

Japanese national health insurance provides universal coverage for inpatient, outpatient, dental and pharmaceutical services. There is a fixed cost-sharing rate that varies with age and a general upper limit on monthly out-of-pocket spending for all age groups.[21] In 2007, the proportion of Japan's total national health expenditure that was publicly financed through a tax transfer and social health insurance programme was 81.9%, which ranks among the highest rates for countries in the Organisation for Economic Co-operation and Development's Asia–Pacific region.[22,23] The remainder is private spending by households, which comprises out-of-pocket medical spending for services that may or may not be covered (e.g. non-prescribed over-the-counter medications) by the universal programme.[22]

Although the exact proportion of patient cost sharing under the public insurance scheme is fixed across services, the level varies by age and income. In particular, in 2001 the Japanese government introduced a system of two different cost-sharing rates: 30% for adults aged less than 70 years and 10% for those aged 70 years or older who had a relatively low income. The rate remained 30% for older individuals with a sufficiently high income.[24] We took advantage of this natural experiment to investigate the effect of the change in patient cost sharing at the age of 70 years on physical and mental health.

Methods

Study population

We obtained data from the 2007 Comprehensive Survey of People's Living Conditions – a nationally-representative, cross-sectional survey administered by the Japanese Ministry of Health, Labour and Welfare.[25] In total, 2000 sampling units were randomly selected from all 47 prefectures in Japan. All individuals and households in each unit were asked to complete a self-administered questionnaire in July 2007. We restricted our study population to 10 906 individuals aged between 64 and 75 years (i.e. 70 ± 6 years). We excluded individuals who were hospitalized or institutionalized ($n = 408$) and those who were eligible for free health care ($n = 205$). For the remaining 10 293, we performed multiple imputation to address potential bias

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(Submitted: 2 October 2011 – Revised version received: 16 December 2011 – Accepted: 9 January 2012 – Published online: 12 February 2012)

due to missing data (e.g. data on general health status were missing for 13.3%).

Since 2001, the cost-sharing rate is normally reduced from 30% to 10% in the first month after people turn 70 years of age, provided their annual taxable income is below 12 000 United States dollars (US$), which was equivalent to 1.45 million Japanese yen in July 2007.[24] Overall, 83.3% of the study population was eligible for the reduction in 2007.

Study variables

We analysed three dependent variables: out-of-pocket medical spending, physical health and mental health. Out-of-pocket spending included all expenditure on medical services in the month preceding the survey. We used a 16-point summary physical health measure developed for the Comprehensive Survey of People's Living Conditions.[26,27] A summary physical health score was derived for each individual from answers to questions on general health status, mobility, self-care and activities of daily living, and pain, as described in a footnote to Table 1. Mental health status was assessed using a Japanese version of the Kessler-6 24-point scale, which has been validated as a strong predictor of mental disorders, excluding substance use disorder, that can be identified using the Structured Clinical Interview of the *Diagnostic and statistical manual of mental disorders, fourth edition* and that have a Global Assessment of Functioning score less than 60.[28–31] We reversed the original Kessler-6 scale such that 24 was the best score and 0, the worst.

For modelling purposes, we created a dichotomous indicator, designated *age ≥ 70dummy*: the indicator equalled 1 if the participant was 70 years of age or older and 0 otherwise. A second dichotomous indicator, designated *income eligibility*, equalled 1 if the participant was eligible for the lower cost-sharing rate because of his or her taxable income, and 0 otherwise.

To adjust for potential confounders, we considered the following covariates in the regression models: gender, marital status, household size, occupational status, house ownership and the size of the settlement where the individual lived. In addition, we carried out separate analyses for participants who did and those who did not report health-care use under the public insurance programme at the time of the survey for at least one chronic illness that had been diagnosed at a clinic or hospital.

Statistical analysis

The effect of the reduction in the cost-sharing rate at the age of 70 years on out-of-pocket medical spending, physical health and mental health was quantified by estimating the discontinuity in the age trend of these outcomes using a regression discontinuity design.[17,32] We assumed that out-of-pocket spending and physical and mental health scores would vary smoothly with age in the absence of the rate reduction and attributed any abrupt deviation in the age trend at the age of 70 years to that reduction. Deviations were quantified, first, by estimating the difference between the value of a variable for individuals aged 69 years and 11 months and the value for those in the first month of their 70th year and, second, by determining how much of that difference could not be explained by the trend observed from the age range of 64 to 69 years to the age range of 70 to 74 years.

We fitted the following unadjusted linear model for the three study outcomes:

$$E(Y) = \beta_0 + \beta_1(age) + \beta_2(age)^2 + \beta_3(age \geq 70dummy) \quad (1)$$

where $E(Y)$ is the expected value of the dependent variable, *age* is given in years and $age \geq 70dummy$ is as described above. Thus, β_3 provides a measure of the discontinuity in $E(Y)$ around the age of 70 years and can be interpreted as the effect of the cost-sharing rate reduction. To determine whether the effect observed varied by eligibility for the rate reduction, we fitted separate models for non-eligible and eligible adults.

In secondary analyses, we fitted joint models with interaction terms that compared discontinuities between non-eligible and eligible adults and derived differential discontinuities for eligible adults. These differential discontinuities provided more robust estimates of the effects of cost sharing by controlling for changes in the health of non-eligible adults between the ages of 69 and 70 years. However, our study sample had limited statistical power for estimating these differential effects. In addition, to determine how health-care needs affected outcomes in eligible adults, we fitted separate and joint models for eligible adults who were or were not receiving health care at the time of the survey.

To check a key assumption of the regression discontinuity design, we confirmed that important characteristics of the study participants did not change around the age of 70 years.[17,32] Specifically, we used the models described above to look for age discontinuities in sociodemographic factors among eligible adults, such as gender, marital status, household size, occupational status, house ownership, taxable income and the size of the settlement where the individual lived. All *P*-values for these factors were found to be greater than 0.25, which confirms that the characteristics did not abruptly change at the age of 70 years.

Furthermore, we adjusted the above models for these sociodemographic characteristics and used multiple imputation to address bias that could have been introduced by missing data on outcome variables and covariates, as explained in a footnote to Table 2.[33] Therefore, our main results were adjusted for sociodemographic characteristics and multiple imputation.

To understand the clinical significance of the average change in mental health status associated with reduced cost sharing, we used logistic regression to estimate the associated change in the prevalence of mild mental illness. We used a validated threshold for the diagnosis of mental illness (i.e. any mood or anxiety disorder in the *Diagnostic and statistical manual of mental disorders, fourth edition*) in Japan: a score of 19 or less on our reversed Kessler-6 scale.[30]

We carried out several sensitivity analyses. First, we progressively narrowed the age cohort to individuals aged between 67 and 72 years and then to those between 69 and 70 years. Second, we estimated discontinuities across 11 different dichotomous indicators for age thresholds ranging from 65 to 75 years. We used generalized estimating equations to account for correlated observations within households when estimating standard errors and conducting two-sided tests.[34,35] Analyses were performed using Stata version 12.0 (StataCorp. LP, College Station, USA) and R version 2.13.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Significant differences in sociodemographic characteristics and health-care

Table 1. **Demographic characteristics, medical spending and health status of older adults, 2007 Comprehensive Survey of People's Living Conditions, Japan**

Characteristic	Eligible[a] for reduced cost sharing at 70 years of age			Not eligible[a] for reduced cost sharing at 70 years of age		
	Aged 64–69 $n = 3\,837$[c]	Aged 70–75 $n = 3\,769$[c]	P[b]	Aged 64–69 $n = 966$[c]	Aged 70–75 $n = 554$[c]	P[b]
Gender			0.147			0.349
Male, %	40.9	42.6		85.5	83.6	
Female, %	59.1	57.4		14.5	16.4	
Marital status			< 0.001			0.005
Married, %	80.7	74.9		89.1	85.0	
Unmarried, %	2.9	2.2		1.9	3.1	
Widowed, %	11.9	19.3		6.0	10.1	
Divorced, %	4.4	3.6		3.0	1.8	
Household size			0.608			0.055
Mean, no. of persons	2.72	2.73		2.72	2.59	
Standard error, no. of persons	0.023	0.026		0.042	0.059	
Occupational status			< 0.001			< 0.001
Not working, %	12.9	74.5		35.6	59.0	
Working, %	86.3	25.5		64.4	41.0	
House ownership			0.039			0.379
No, %	13.7	12.1		5.9	4.7	
Yes, %	86.3	87.9		94.1	95.3	
Settlement size[d]			0.004			0.919
Metropolitan area, %	15.9	14.1		19.6	21.1	
Large city (population: > 150 000), %	26.8	25.6		30.4	31.2	
Medium city (population: 50 000–150 000), %	27.9	28.3		27.2	26.4	
Small city (population: < 50 000), %	14.7	14.4		10.2	9.6	
Town or village, %	14.6	17.5		12.5	11.7	
Reported health-care use[e]			< 0.001			< 0.001
No, %	39.2	28.6		39.1	27.8	
Yes, %	60.8	71.4		60.9	72.2	
Out-of-pocket medical spending[f]			< 0.001			0.259
Mean, US$	47.6	35.7		49.7	44.8	
Standard error, US$	1.41	1.15		2.66	3.48	
Physical health[g]			< 0.001			< 0.001
Mean score	13.4	13.0		13.8	13.3	
Standard error	0.044	0.053		0.063	0.106	
Mental health[h]			0.397			0.300
Mean score	20.9	21.0		21.6	21.8	
Standard error	0.077	0.083		0.117	0.147	

[a] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for individuals who had an annual taxable income under 12 000 United States dollars (US$).
[b] χ^2 tests were used to compare distributions of categorical variables and t tests were used for continuous variables.
[c] Because values were missing for some variables, the sample sizes for each two-by-two table were smaller than these numbers. Moreover, the total number of individuals was 9126, which is smaller than the number of the study participants ($n = 10\,293$) because data on income eligibility were missing.
[d] The size of the settlement where the individual lived at the time of the Comprehensive Survey of People's Living Conditions.
[e] Health-care use reported at the time of the Comprehensive Survey of People's Living Conditions.
[f] Spending in Japanese yen was converted into US$ using the rate that applied in July 2007 of approximately 120 Japanese yen per US$.
[g] Physical health status was evaluated on a scale of 0 to 16 points and was calculated from the sum of four questionnaire health measures: (i) general health status was assessed by asking, "How is your current health status?" (4 if excellent, 3 if very good, 2 if good, 1 if fair and 0 if poor); (ii) mobility was assessed by asking, "How many days have you been in bed (i.e. bed-ridden) because of health-related problems in the previous one month?" (4 if never, 3 if 1 to 3 days, 2 if 4 to 6 days, 1 if 7 to 14 days and 0 if 15 days or more); (iii) self-care and activities of daily living were assessed by asking, "Do you have difficulty with any of the following four areas in your daily life due to your physical health?: daily movements (e.g. getting up, wearing clothes, eating and bathing); staying outdoors; work, housework or studying; and, exercise or sport" (4 if no difficulties, 3 if difficulty in one area, 2 if difficulty in two areas, 1 if difficulty in three areas and 0 if difficulty in all four areas); (iv) pain was assessed by asking, "Do you have pain in the head, stomach, back or extremities?" (4 if no pain, 3 if pain in one location, 2 if pain in two locations, 1 if pain in three locations and 0 if pain in all four locations).
[h] Mental health status was evaluated on a scale of 0 to 24 points using a reversed version of Japanese Kessler-6 scale, such that 24 was best.

Table 2. **Effect of reduced cost sharing at age 70 years[a] on out-of-pocket medical spending and physical and mental health,[b] Japan, 2007**

Characteristic	n[c]	Unadjusted model[d]			Adjusted model[e]			Multiple imputation model[f]			Joint model with interaction after imputation[g]		
		β_3	SE	P	β_3	SE	P	β_3	SE	P	δ_6	SE	P
Out-of-pocket medical spending	***n***	**US$ per month[h]**	**US$ per month[h]**		**US$ per month[h]**	**US$ per month[h]**		**US$ per month[h]**	**US$ per month[h]**		**US$ per month[h]**	**US$ per month[h]**	
Non-eligible[a] adults	1790	−3.54	8.48	0.676	−4.10	8.69	0.637	−3.16	8.08	0.696	−21.79	8.79	0.014
Eligible adults[a]	8503	−24.93	3.61	< 0.001	−24.92	3.94	< 0.001	−25.25	3.59	< 0.001			
Eligible adults[a] with no reported health-care use[i]	2968	−3.40	4.19	0.417	−3.73	4.27	0.382	−4.19	4.58	0.361	−27.68	6.43	< 0.001
Eligible adults[a] with reported health-care use[i]	5535	−32.72	5.29	< 0.001	−32.76	5.37	< 0.001	−32.44	4.61	< 0.001			
Physical health[j]	***n***	**Score**	**Score**		**Score**	**Score**		**Score**	**Score**		**Score**	**Score**	
Non-eligible[a] adults	1790	−0.31	0.24	0.202	−0.24	0.24	0.326	−0.17	0.15	0.247	0.27	0.16	0.084
Eligible adults[a]	8503	0.12	0.13	0.381	0.08	0.13	0.106	0.10	0.07	0.143			
Eligible adults[a] with no reported health-care use[i]	2968	0.19	0.14	0.173	0.19	0.15	0.202	0.14	0.09	0.115	−0.11	0.13	0.419
Eligible adults[a] with reported health-care use[i]	5535	−0.02	0.17	0.892	−0.04	0.18	0.799	0.02	0.09	0.857			
Mental health[k]	***n***	**Score**	**Score**		**Score**	**Score**		**Score**	**Score**		**Score**	**Score**	
Non-eligible[a] adults	1790	−0.05	0.39	0.888	0.06	0.39	0.873	0.03	0.38	0.932	0.70	0.41	0.086
Eligible adults[a]	8503	0.58	0.20	0.004	0.56	0.20	0.007	0.66	0.18	< 0.001			
Eligible adults[a] with no reported health-care use[i]	2968	0.63	0.32	0.048	0.64	0.32	0.045	0.79	0.32	0.017	−0.29	0.42	0.502
Eligible adults[a] with reported health-care use[i]	5535	0.43	0.27	0.111	0.39	0.28	0.156	0.50	0.23	0.032			

SE, standard error; US$, United States dollars.

[a] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for individuals who had an annual taxable income under 12 000 United States dollars (US$).

[b] The effect of reduced cost sharing was evaluated using a regression discontinuity design and a generalized estimating equation method.

[c] The sample sizes include individuals with missing values, all of whom were included in the imputation model.

[d] We calculated β coefficients for the model: $E(Y) = \beta_0 + \beta_1(age) + \beta_2(age)^2 + \beta_3(age \geq 70\ dummy)$, where $E(Y)$ is the expected value of the dependent variable, namely out-of-pocket medical spending, physical health or mental health, *age* is given in years and $age \geq 70 dummy$ is a dichotomous indicator that equalled 1 if the participant was 70 years or older and 0 otherwise. No other control variables were used in the unadjusted model.

[e] The adjusted model included the control variables: gender, marital status, household size, occupational status, house ownership and the size of the settlement where the individual lived at the time of the Comprehensive Survey of People's Living Conditions. Income was not included as it was used to determine whether an individual was eligible for reduced cost sharing. However, including income in the models did not substantially change the results.

[f] For multiple imputation, we used all the variables described in the methods section and an importance-resampling expectation-maximization algorithm with the assumption that values were missing at random. Five data sets generated from the multiple imputation were mobilized and pooled for point estimation. The same control variables included in the adjusted model were used in the multiple imputation and subsequent regression analyses. Since missing values were estimated and filled in, the standard errors in the imputation model should smaller than those in unadjusted or adjusted model.

[g] We calculated δ coefficients for the model: $E(Y) = \delta_1(age) + \delta_2(age)^2 + \delta_3(age \geq 70dummy) + \delta_4(age) \times$ (income eligibility or reported health-care use) $+ \delta_5(age)^2 \times$ (income eligibility or reported health-care use) $+ \delta_6(age \geq 70dummy) \times$ (income eligibility or reported health-care use) $+ \Sigma\delta$(control variables), where $E(Y)$ is the expected value of the dependent variable, namely out-of-pocket medical spending, physical health or mental health, *age* is given in years and $age \geq 70dummy$ is a dichotomous indicator that equalled 1 if the participant was 70 years or older and 0 otherwise. Coefficients were calculated between adults who were or were not eligible for reduced cost sharing and between eligible adults who did or did not report health-care use at the time of the survey. The main effect was measured by δ_6.

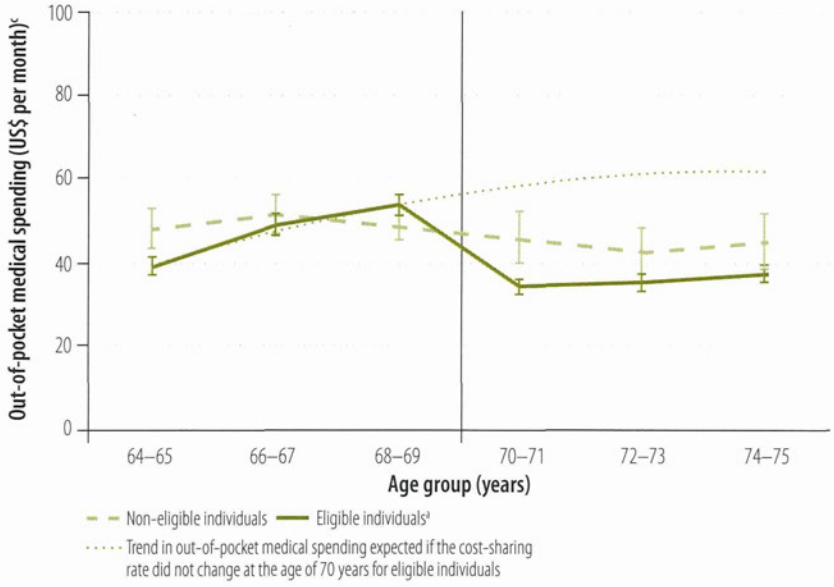
[h] Spending in Japanese yen was converted into US$ using the rate that applied in July 2007 of approximately 120 Japanese yen per US$.

[i] Health-care use reported at the time of the Comprehensive Survey of People's Living Conditions.

[j] Physical health status was evaluated on a scale of 0 to 16 points and was calculated as described in a footnote to Table 1

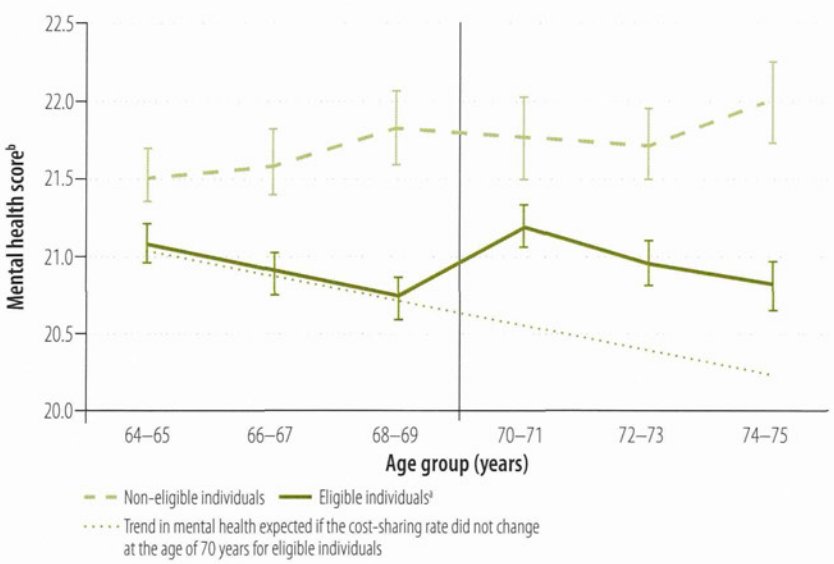
[k] Mental health status was evaluated on a scale of 0 to 24 points using a reversed version of Japanese Kessler-6 scale, such that 24 was best.

Fig. 1. **Effect of reduced cost sharing at age 70 years[a] on out-of-pocket medical spending,[b] Japan, 2007**



US$, United States dollars.
The vertical bars represent standard errors.
[a] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for eligible individuals, who had an annual taxable income under 12 000 United States dollars (US$).
[b] Out-of-pocket medical spending includes expenditure both on items covered by public health-care insurance and items that are not covered, such as over-the-counter medicines.
[c] Spending in Japanese yen was converted into US$ using the rate that applied in July 2007 of approximately 120 Japanese yen per US$.

Fig. 3. **Effect of reduced cost sharing at age 70 years[a] on mental health,[b] Japan, 2007**



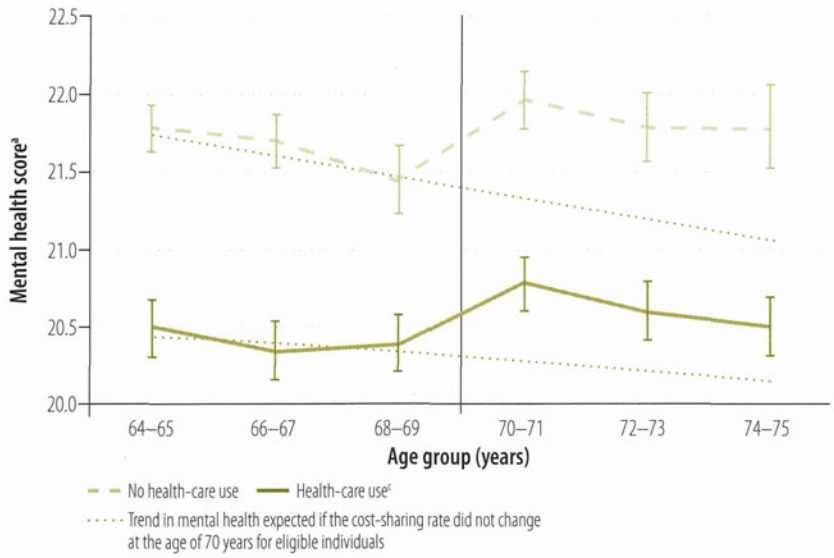
The vertical bars represent standard errors.
[a] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for eligible individuals, who had an annual taxable income under 12 000 United States dollars (US$).
[b] Mental health was evaluated on a scale of 0 to 24 points using a reversed version of Japanese Kessler-6 scale, such that 24 was best.

needs were found between participants aged from 64 to 69 years and those aged from 70 to 75 years (Table 1). Table 2 shows that adjustment for sociodemographic covariates and multiple imputation to address bias due to missing data did not substantially alter the results of the analysis. Although out-of-pocket medical spending by adults who were not eligible for lower cost sharing did not change significantly at the age of 70 years ($\beta_3 = -3.16$ US$/month; $P = 0.696$; Table 2, multiple imputation model), spending by eligible adults decreased significantly and abruptly ($\beta_3 = -25.25$ US$/month; $P < 0.001$), as shown in Fig. 1. There was no significant discontinuity in physical health score at the age of 70 years in either group (Fig. 2, available at: http://www.who.int/bulletin/volumes/90/6/11-095380, and Table 2). However, the differential discontinuity in physical health score for eligible adults ($\delta_6 = +0.27$; $P = 0.084$, joint model with interaction after imputation) showed a relative improvement that approached statistical significance (Table 2). On the other hand, there was a significant improvement in mental health status in the eligible group at the age of 70 years ($\beta_3 = 0.66$; $P < 0.001$; Table 2, multiple imputation model) but not in the non-eligible group ($\beta_3 = 0.03$; $P = 0.932$), as shown in Fig. 3. This improvement was significant even among participants who reported no health-care use at the time of the survey ($\beta_3 = 0.79$; $P = 0.017$), as shown in Fig. 4.

When eligible participants were divided into two subgroups with different health-care needs, the decrease in out-of-pocket spending at the age of 70 years was found to be greater among adults who reported health-care use at the time of the survey than in those who did not ($P < 0.001$ for interaction, Table 2), as shown in Fig. 5. In contrast, the effect of reduced cost sharing on mental health status was similar in the two subgroups ($P = 0.502$ for interaction), as was the effect on physical health status ($P = 0.419$ for interaction), as shown in Fig. 6 (available at: http://www.who.int/bulletin/volumes/90/6/11-095380).

Logistic regression analysis showed that the prevalence of mild mental illness decreased significantly at the age of 70 years among eligible participants (odds ratio, OR: 0.718; $P = 0.009$), but

Fig. 4. **Effect of reduced cost sharing at age 70 years on the mental health[a] of eligible individuals[b] using and not using health-care,[c] Japan, 2007**



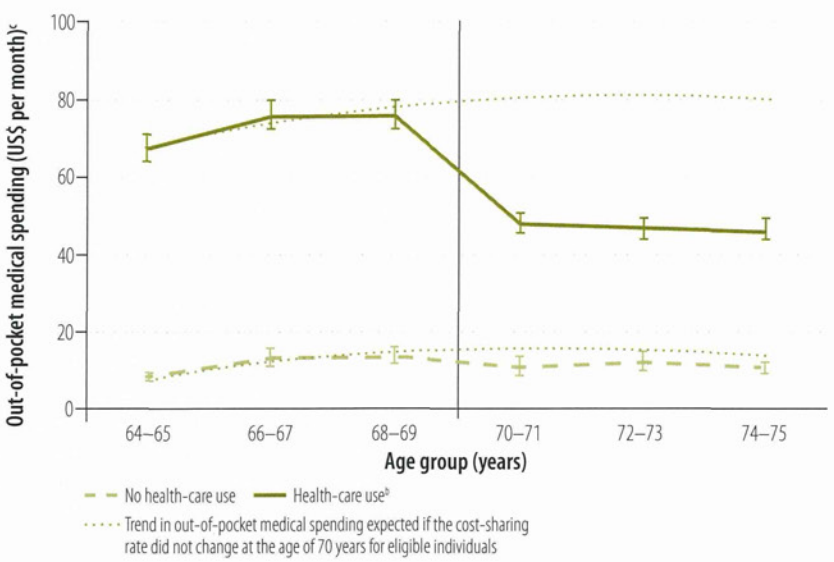
The vertical bars represent standard errors.

[a] Mental health was evaluated on a scale of 0 to 24 points using a reversed version of Japanese Kessler-6 scale, such that 24 was best.

[b] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for eligible individuals, who had an annual taxable income under 12 000 United States dollars (US$).

[c] Health-care use reported at the time of the 2007 Comprehensive Survey of People's Living Conditions.

Fig. 5. **Effect of reduced cost sharing at age 70 years on out-of-pocket medical spending of eligible individuals[a] using and not using health-care,[b] Japan, 2007**



US$, United States dollars.

The vertical bars represent standard errors.

[a] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for eligible individuals, who had an annual taxable income under 12 000 United States dollars (US$).

[b] Health-care use reported at the time of the 2007 Comprehensive Survey of People's Living Conditions.

[c] Spending in Japanese yen was converted into US$ using the rate that applied in July 2007 of approximately 120 Japanese yen per US$.

not among non-eligible participants (OR: 0.984; $P = 0.960$). When we incrementally narrowed the age range of participants included in the analysis from the initial 64 to 75 years, the estimated effect of reduced cost sharing on mental health became progressively larger: β_3 was 0.66 ($P < 0.001$) for the age range 64 to 75 years, 0.69 ($P = 0.022$) for the range from 67 to 72 years and 1.19 ($P = 0.047$) for the range from 69 to 70 years. Finally, of the 11 dichotomous indicators for the different age thresholds investigated, only that for a threshold of 70 years was associated with a significant discontinuity in mental health scores.

Discussion

In this nationally representative study, we found that a reduction in health-care cost sharing from 30% to 10% at the age of 70 years was associated with a significant decrease in out-of-pocket medical spending and a significant improvement in mental health in Japanese adults. There was also a relative improvement in physical health in those eligible for the reduction by comparison with those who were not eligible, but it was not significant. Nevertheless, the relative improvement in physical health was similar to that observed in a larger longitudinal study,[18] which suggests that our study was not adequately powered to detect this effect. Furthermore, the sharp regression discontinuity design captured only the immediate effect of the cost sharing reduction and may have missed improvements that become manifest over time.

Our findings are largely consistent with previous studies of the effect that providing Medicare coverage in the United States after the age of 65 years has on health-care utilization and health outcomes: coverage was associated with an abrupt increase in health-care utilization and improvements in physical and mental health, mortality and disparities in disease control.[9,14–19] In addition, higher cost sharing among insured adults has been linked to less use of clinical services and adverse effects on health outcomes.[8,9,14–20,36]

Our findings on out-of-pocket medical spending are consistent with the results of the RAND Health Insurance Experiment,[12] which reported

that reduced cost sharing substantially increased both total health-care utilization and total health-care spending. Although we could not measure total health-care spending directly, we were able to estimate it in the following way. Data from a separate nationally representative survey indicate that out-of-pocket spending on services included in Japan's universal insurance coverage programme constitutes 70% of all out-of-pocket medical spending by elderly Japanese adults whose health care is covered by the programme, while spending on services that are not covered (e.g. over-the-counter medications) accounts for the remaining 30%.[37] If total health-care spending is unchanged by reduced cost sharing, out-of-pocket spending by eligible adults should decrease to one third (i.e. from 30% to 10%). However, the observed value of out-of-pocket medical spending by eligible adults aged between 70 and 71 years was 29% higher than expected, which suggests that both total health-care spending and utilization had increased substantially and that this may have influenced mental and physical health.

The mental health gains we observed suggest that reduced cost sharing helped alleviate depression and anxiety, which are known to be the largest contributors to disability globally.[38] Surprisingly, the improvement in mental health was even observed in individuals who were not using health-care services, which suggests that reduced cost sharing may have affected mental health in several ways. Individuals may have benefited from increased use of health-care services or from the greater sense of security provided by more affordable insurance coverage.

Policy implications

One topic for debate is whether, from a societal or governmental perspective, the gain in mental health linked to reduced cost sharing is worth the associated increase in health-care spending.[39–41] Fostering a sense of security is one of the core functions of universal health insurance coverage and our findings suggest that the Japanese government has ameliorated the burden of mental illness among the elderly by reducing their cost-sharing rate.[2,42,43] However, because of fiscal constraints, in April 2008 the Japanese government decided to raise the cost-sharing rate from 10% to 20% after the age of 70 years, perhaps in 2012 or 2013.[24,44] This decision is likely to become a major issue in the next national election. Closer follow-up of the effect of this policy change on population health and medical expenditure would provide the information policy-makers in medium- to high-income countries need to design a system of universal health insurance coverage that incorporates the optimum cost-sharing rate for elderly populations.

Limitations

A lack of survey data on chronic conditions prevented us from being able to identify individuals with treatable chronic conditions, such as cardiovascular disease and diabetes, whose health status may have been particularly affected by reduced cost sharing.[14,15,18]

In addition, because our study used a cross-sectional rather than a longitudinal design, the results may have been affected by selection bias. For example, in general, individuals who were not using health care between the ages of 64 and 69 years were more likely to use health care after the age of 70 years following the cost sharing reduction.[12] However, those who did not start using health care after the age of 70 years were likely to be healthier than those who did. The effect would be an abrupt change in the composition of cross-sectional comparison group samples, which would probably lead to an underestimate of the mental and physical health benefits for the group using health care and an overestimate of the benefits for those not using health care. Thus, although strong conclusions can be drawn from our analysis about changes in mental health for the entire study sample, the results obtained by stratifying participants by use of health care should be interpreted with caution.

Finally, the fact that our study did not have a randomized experimental design makes it impossible to infer a cause and effect relationship when interpreting the findings. In particular, because eligibility for the cost-sharing reduction was determined by income, it was not possible to match the income distribution in eligible and non-eligible groups. Nevertheless, we used a strong regression discontinuity design to control for all observed and unobserved characteristics that trended smoothly with age in our study sample.[32,45,46] Furthermore, our analysis included difference-in-difference comparisons that adjusted the effect of cost sharing on eligible adults for changes in physical and mental health observed in the non-eligible, or control, group.

In summary, a reduction in health-care cost sharing at the age of 70 years was associated with lower out-of-pocket medical spending and improved mental health in Japanese adults. This finding suggests that governments in medium- and high-income countries with universal health insurance coverage can reduce the burden of depression and anxiety by modifying cost sharing. The proposed increase in patient cost sharing currently under consideration by the Japanese government deserves close scrutiny because it may have an adverse effect on the mental, and possibly physical, health of older adults. ■

Acknowledegments

Akihiro Nishi is supported by the Nakajima Foundation. We thank Gary King at Harvard University, John Z Ayanian and Sae Takada at Harvard Medical School and Keiko Sakurai at the University of Tokyo.

Funding: We were funded by the Japanese Ministry of Health, Labour and Welfare (H22-Policy-033), the Bill & Melinda Gates Foundation, the China Medical Board, the Beeson Career Development Award Program (NIA K08 AG038354) and the American Federation for Aging Research.

Competing interests: None declared.

ملخص

الفوائد الصحية لخفض تقاسم التكاليف من جانب المرضى في اليابان

الغرض تقييم التأثير على الإنفاق الطبي من الأموال الخاصة والصحة البدنية والنفسية الناتج عن خفض اليابان لتقاسم تكاليف الرعاية الصحية من 30 ٪ إلى 10 ٪ عند بلوغ سن الفرد 70 عامًا.

الطريقة تم استقاء بيانات الدراسة من استقصاء متعدد القطاعات ممثل للواقع على الصعيد الوطني تم إجراؤه في عام 2007 على عينة من 10293 بالغًا تتراوح أعمارهم من 64 إلى 75 عامًا. وخضعت الصحة البدنية للتقييم باستخدام مقياس من 16 نقطة استنادًا إلى البيانات التي يفصح عنها الأشخاص والمعنية بالصحة العمومية والتنقل والرعاية الذاتية وأنشطة المعيشة اليومية والألم. كما خضعت الصحة النفسية للتقييم باستخدام مقياس من 24 نقطة استنادًا إلى أداة كسلر6- للضائقة النفسية غير المحددة. وتم تقييم تأثير خفض تقاسم التكاليف باستخدام تصميم انقطاع الارتداد.

النتائج بالنسبة للبالغين الذين تتراوح أعمارهم من 70 إلى 75 عامًا الذين يحصلون على دخل يجعلهم غير مؤهلين لخفض تقاسم التكاليف، لم يختلف الإنفاق من الأموال الخاصة أو النتائج الصحية عن القيم المتوقعة على أساس الاتجاه الذي لوحظ في الأعمار التي تتراوح من 64 إلى 69 عامًا. إلا أنه بالنسبة للبالغين المؤهلين ممن تتراوح أعمارهم من 70 إلى 75 عامًا، كان الإنفاق من الأموال الخاصة أكثر انخفاضًا بشكل كبير (الاحتمالية < 0.001) وكانت الصحة النفسية أفضل بشكل كبير (الاحتمالية < 0.001) عن المتوقع. علاوة على ذلك، تشابهت فوائد الصحة النفسية لدى الأفراد الذين كانوا يستخدمون ولا يستخدمون خدمات الرعاية الصحية (الاحتمالية = 0.502 للتفاعل). ومال التحسن في الصحة البدنية بعد عمر 70 عامًا لدى البالغين المؤهلين لانخفاض تقاسم التكاليف إلى الزيادة عنه لدى البالغين غير المؤهلين (الاحتمالية = 0.084).

الاستنتاج ارتبط انخفاض تقاسم التكاليف بانخفاض الإنفاق الطبي من الأموال الخاصة وتحسين الصحة النفسية لدى البالغين اليابانيين الأكبر سنًا.

摘要

日本降低病人费用分担的健康益处

目的 评估日本将达到 70 岁的人的医疗保健费用分担从 30 % 减至 10% 对现款医疗费用和身体及心理健康的影响。

方法 研究数据来自 2007 年对 10293 位 64 至 75 岁的成年人的全国代表性横断面调查。基于有关一般健康、活动性、自理、日常生活活动和病痛的自报数据，采用 16 分制评估身体健康状况。基于非特异性心理困扰的 Kessler-6 仪器，采用 24 分制评估心理健康状况。使用回归间断设计估计降低费用分担的影响。

结果 对于其收入水平使其无资格享受降低费用分担政策且年龄在 70 至 75 岁的成年人，无论是现款费用还是健康状况都不同于在基于 64 - 69 岁的人群中观察到的趋势期望值。然而，对于享有资格的 70 至 75 岁的成年人，现款费用显著低于预期（$P < 0.001$），心理健康状况显著好于预期（$P < 0.001$）。这些差异突现在 70 岁的人群中。此外，在使用和不使用医疗保健服务的个人当中，心理健康状态的益处相似（交互作用 $P = 0.502$）。有资格享受降低费用共享政策的 70 岁之后的成年人的身体健康的改善程度有大于无资格的成年人的趋势（$P = 0.084$）。

结论 降低费用分担与更少的现款医疗费用和更好的日本老年人的心理健康存在关联。

Résumé

Avantages sanitaires de la réduction du partage des coûts au Japon

Objectif Évaluer l'incidence sur les dépenses médicales personnelles et la santé physique et mentale de la réduction de 30% à 10% du partage des coûts de soins de santé lorsque les individus atteignent 70 ans.

Méthodes Les données de l'étude proviennent d'une enquête nationale transversale, effectuée en 2007, sur 10 293 adultes âgés de 64 à 75 ans. Leur santé physique a été évaluée au moyen d'une échelle de 16 points, basée sur des données autodéclarées de santé générale, de mobilité, de soins auto-administrés, d'activités de la vie quotidienne et de douleur. Leur santé mentale a été évaluée au moyen d'une échelle de 24 points sur la base de l'instrument Kessler-6 de détresse psychologique non spécifique. L'effet de la réduction du partage des coûts a été estimé en utilisant une approche de discontinuité de la régression.

Résultats Pour les individus âgés de 70 à 75 ans inéligibles, en raison de leurs revenus, à une réduction du partage des coûts, ni les dépenses de santé personnelles ni les résultats sanitaires ne différaient des valeurs attendues, sur la base de la tendance observée chez les 64 à 69 ans. Toutefois, pour les individus âgés de 70 à 75 ans ayant droit à cette réduction, les dépenses personnelles étaient significativement plus faibles ($P < 0,001$) et leur santé mentale significativement meilleure ($P < 0,001$) que prévu. Ces différences sont apparues brutalement à l'âge de 70 ans. En outre, les avantages en termes de santé mentale étaient similaires chez les individus recourant ou non aux services de santé ($P = 0,502$ pour l'interaction). L'amélioration de la santé physique après l'âge de 70 ans chez les adultes éligibles à une réduction du partage des coûts avait tendance à être supérieure à celle des adultes inéligibles ($P = 0,084$).

Conclusion La réduction du partage des coûts était associée à une baisse des dépenses médicales personnelles et à une amélioration de la santé mentale des personnes âgées japonaises.

Резюме

Повышение эффективности здравоохранения при сокращении участия пациентов в покрытии затрат в Японии

Цель Оценить, как сокращение участия пациентов, достигших 70-летнего возраста, в покрытии затрат на медицинское обслуживание в Японии с 30% до 10% влияет на суммы, выплачиваемые за медицинские услуги, а также на физическое и психическое здоровье.

Методы Данные для исследования получены из проведенного в 2007 г. национально-репрезентативного перекрестного анкетирования 10293 взрослых пациентов в возрасте от 64 до 75 лет. Состояние физического здоровья оценивалось при помощи теста из 16 пунктов на основании данных, предоставленных участниками, о состоянии здоровья в целом, подвижности, уходе за собой, ежедневной деятельности и болевых ощущениях. Состояние психического здоровья определялось с помощью теста из 24 пунктов, основанного на методе оценки неспецифических психических расстройств Kessler-6. Влияние сокращения участия пациентов в покрытии затрат оценивалось с использованием модели разрывной регрессии.

Результаты Для взрослых пациентов в возрасте от 70 до 75 лет, чей доход лишал их права на сокращение участия в покрытии затрат, ни оплачиваемые пациентами расходы, ни состояние их здоровья не отличались от значений, полученных на основании тенденций, которые наблюдалась у 64-69-летних. Однако для имеющих такое право взрослых пацентов в возрасте от 70 до 75 лет оплачиваемые пациентами расходы на медицинское обслуживание были значительно ниже ($P < 0,001$), а психическое здоровье значительно лучше ($P < 0,001$) ожидаемых. Данные различия начинали резко проявляться в возрасте 70 лет. Более того, польза для психического здоровья пользовавшихся и не пользовавшихся медицинским обслуживанием лиц была сходной ($P = 0,502$ для взаимосвязи). Улучшение физического здоровья у взрослых старше 70 лет, имеющих право на сокращение участия в покрытии затрат, было более заметным чем у тех, кто такого права не имел ($P = 0,084$).

Вывод Сокращение участия в покрытии затрат продемонстрировало уменьшение оплачиваемых пацинтом расходов на медицинское обслуживание, а также лучшее психическое здоровье у японцев пожилого возраста.

Resumen

Beneficios sanitarios de la participación reducida en los gastos en Japón

Objetivo Evaluar el efecto de la reducción del 30% al 10% de la participación en los gastos de asistencia sanitaria sobre los gastos médicos directos y la salud física y mental en personas mayores de 70 años en Japón.

Métodos Los datos de estudio se obtuvieron de una encuesta transversal representativa realizada a nivel nacional entre 10.293 adultos con edades comprendidas entre los 64 y los 75 años. La salud física se evaluó por medio de una escala de 16 puntos en función de los datos dados por los encuestados sobre salud general, movilidad, cuidados personales, actividades de la vida diaria y dolor. La salud mental se evaluó por medio de una escala de 24 puntos en función del instrumento Kessler-6 para la angustia psicológica no específica. El efecto de la participación reducida en los gastos se calculó utilizando un diseño de regresiones en discontinuidad.

Resultados Entre los adultos con edades comprendidas entre los 70 y 75 años, cuyos ingresos no les permitían ser seleccionados para la participación reducida en los gastos, ni los gastos directos ni los costes sanitarios difirieron de los valores esperados en función de la tendencia observada entre los adultos con edades comprendidas entre los 64 y los 69 años. No obstante, los gastos directos fueron significativamente inferiores ($P < 0,001$) y la salud mental fue significativamente mejor ($P < 0,001$) de lo esperado entre los adultos elegibles con edades comprendidas entre los 70 y los 75 años. Estas diferencias surgieron de manera repentina a la edad de 70 años. Además, los beneficios sobre la salud mental fueron similares tanto en individuos que utilizaban los servicios de asistencia sanitaria como en aquellos que no lo hacían ($P = 0,502$ de interacción). La mejora en la salud física a partir de los 70 años en adultos elegibles para la participación reducida en los gastos mostró una tendencia superior que en los adultos no elegibles ($P = 0,084$).

Conclusión La participación reducida en los gastos se asoció con la reducción de los gastos médicos directos y mejoró la salud mental de los adultos japoneses de mayor edad.

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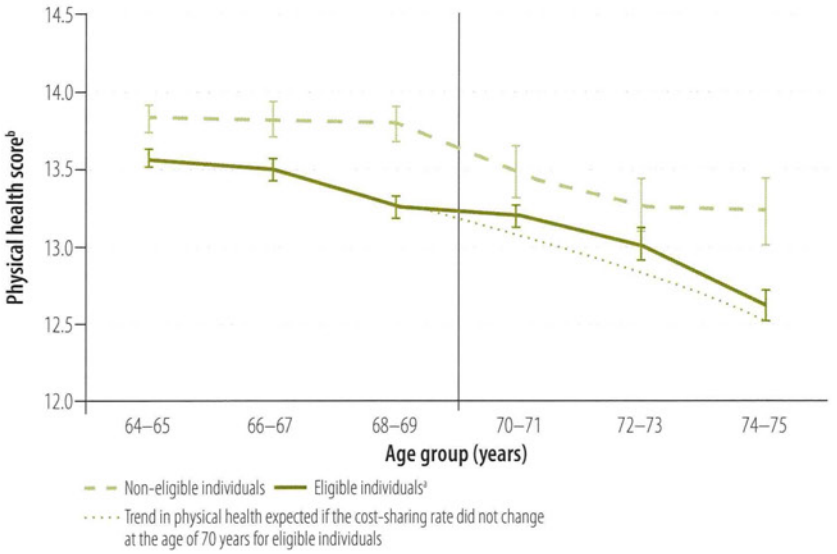
Fig. 2. **Effect of reduced cost sharing at age 70 years[a] on physical health,[b] Japan, 2007**

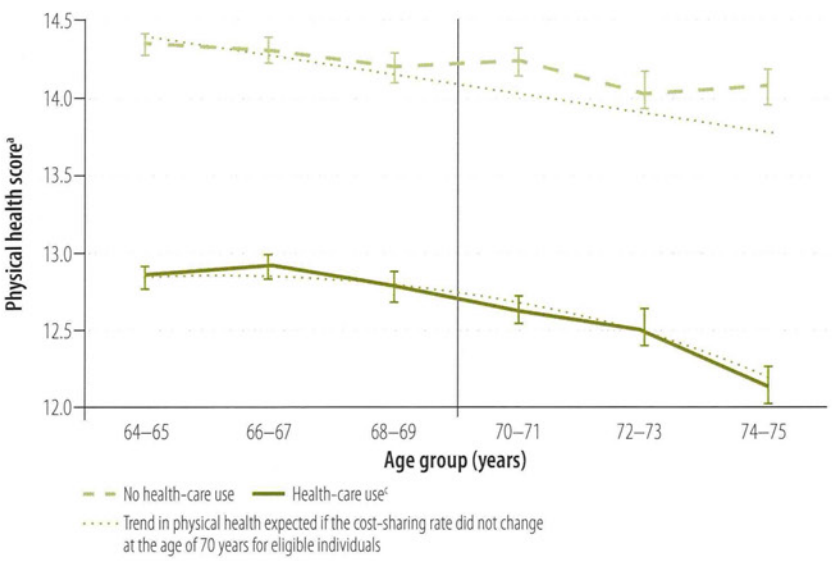


The vertical bars represent standard errors.

[a] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for eligible individuals, who had an annual taxable income under 12 000 United States dollars (US$).

[b] Physical health status was evaluated on a scale of 0 to 16 points and was calculated as described in a footnote to Table 1.

Fig. 6. **Effect of reduced cost sharing at age 70 years on the physical health[a] of eligible individuals[b] using and not using health-care,[c] Japan, 2007**



The vertical bars represent standard errors.

[a] Physical health status was evaluated on a scale of 0 to 16 points and was calculated as described in a footnote to Table 1.

[b] The cost-sharing rate decreased from 30% to 10% at the age of 70 years for eligible individuals, who had an annual taxable income under 12 000 United States dollars (US$).

[c] Health-care use reported at the time of the 2007 Comprehensive Survey of People's Living Conditions.

Yasunaga et al. BMC Health Services Research 2012, 12:129
http://www.biomedcentral.com/1472-6963/12/129

BMC
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RESEARCH ARTICLE Open Access

Variation in cancer surgical outcomes associated with physician and nurse staffing: a retrospective observational study using the Japanese Diagnosis Procedure Combination Database

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Abstract

Background: Little is known about the effects of professional staffing on cancer surgical outcomes. The present study aimed to investigate the association between cancer surgical outcomes and physician/nurse staffing in relation to hospital volume.

Methods: We analyzed 131,394 patients undergoing lung lobectomy, esophagectomy, gastrectomy, colorectal surgery, hepatectomy or pancreatectomy for cancer between July and December, 2007–2008, using the Japanese Diagnosis Procedure Combination database linked to the Survey of Medical Institutions data. Physician-to-bed ratio (PBR) and nurse-to-bed ratio (NBR) were determined for each hospital. Hospital volume was categorized into low, medium and high for each of six cancer surgeries. Failure to rescue (FTR) was defined as a proportion of inhospital deaths among those with postoperative complications. Multi-level logistic regression analysis was performed to examine the association between physician/nurse staffing and FTR, adjusting for patient characteristics and hospital volume.

Results: Overall inhospital mortality was 1.8%, postoperative complication rate was 15.2%, and FTR rate was 11.9%. After adjustment for hospital volume, FTR rate in the group with high PBR (≥19.7 physicians per 100 beds) and high NBR (≥77.0 nurses per 100 beds) was significantly lower than that in the group with low PBR (<19.7) and low NBR (<77.0) (9.2% vs. 14.5%; odds ratio, 0.76; 95% confidence interval, 0.68–0.86; $p < 0.001$).

Conclusions: Well-staffed hospitals confer a benefit for cancer surgical patients regarding reduced FTR, irrespective of hospital volume. These results suggest that consolidation of surgical centers linked with migration of medical professionals may improve the quality of cancer surgical management.

Background

Cancer is one of the major causes of death in developed nations, and it is the leading cause of death in Japan [1]. The frequency of cancer surgeries has also been increasing in Japan from 30,605 per month in 1996 to 44,010 per month in 2008 [2], presumably due to population ageing, improved access to cancer screening, and a wider use of surgery because of development of less invasive approaches for previously untreatable patients. With the rise of cancer surgical cases, better allocation of limited healthcare resources is crucial to optimize cancer surgical management and improve operative outcomes.

Numerous studies have reported an association between hospital volume and cancer surgical outcomes in the US [3-5] and Japan [6-9]. Previous studies have also suggested that professional staffing is associated with better short-term outcomes, including physician staffing [10-12] and nurse staffing [13-15]. However, little is known about the concurrent effects of professional staffing and hospital volume on surgical outcomes.

Japan is unique in that the numbers of physician/nurses per bed are extremely low compared with Western standards; there are 26.5 physicians and 117.8 nurses per 100 beds in Japan, while there are 96.1 and 268.1,

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respectively, in Organization for Economic Cooperation and Development countries [16]. This situation has been created by an excess in the number of hospitals and beds. Regarding nurse staffing, the Japanese government has established standard criteria for the nurse-to-bed ratio in the public health insurance system, which has given hospital administrators a financial incentive to increase the nurse-to-bed ratio. With regard to physician staffing, only the minimum standard (at least 1 physician per 16 acute care beds in Medical Service Law) is set without further incentives to raise the physician-to-bed ratio, which varies widely between hospitals. Under such an extremely low end of staffing, improvement of professional staffing remains an important policy issue in Japan [17].

In the present study, we hypothesized that better staffing of physicians and nurses, even in the extremely low end observed in Japan, is independently associated with better postoperative early outcomes following cancer surgery, irrespective of hospital volume. To prove this hypothesis, we used a national inpatient database in Japan, and performed multivariate analyses to confirm the relation between physician/nurse staffing and operative outcomes, adjusting for hospital volume as well as patient characteristics. Regarding outcome measures, we used the "failure to rescue"—mortality among patients with postoperative complications—because how successfully hospitals rescue patients from surgical complications may be a sensitive indicator for evaluating quality of surgical care [18,19].

A better understanding of the relationship between professional staffing and outcomes may lead to health policy innovation for more efficient resource allocation to increase the benefit to cancer surgical patients. We discuss the implications of our results that could be useful for health policy decision makers in any country.

Methods

Data source

We used the Diagnosis Procedure Combination (DPC) database and the Survey of Medical Institutions data. The DPC is a case-mix patient classification system, launched in 2002 by the Ministry of Health, Labour and Welfare of Japan, and is linked with a lump-sum per-diem payment system. All the 82 university hospitals are obliged to adopt the DPC system, but participation by other community hospitals, private or public, is voluntary. Participating hospitals included 855 in 2008, covering approximately 2.9 million inpatients, or approximately 40% of all acute care inpatient hospitalizations in Japan. For this study, we used the data of 2007 and 2008 that included 5.85 million discharge cases.

The DPC system mandates participating hospitals to have electronic submission of claim bills and some clinical data of all the patients discharged between July 1 and December 31 each year, and a copy of the submitted data was collected for research purposes by the research group. The database includes the following: patients' age and sex; main diagnoses, pre-existing comorbidities, and post-admission complications coded by the International Classification of Disease and Related Health Problems, 10th Revision (ICD-10) codes; and surgical procedures coded by the Japanese original surgical coding system, which is comparable with the ICD, 9th Revision, Clinical Modification (ICD-9-CM) codes. The data also include discharge status [20,21]. In the DPC database, complications that occurred after admission are clearly differentiated from comorbidities that were already present at admission. To optimize the accuracy of the recorded diagnoses, physicians in charge are obliged to record the diagnoses with reference to medical charts.

The Survey of Medical Institutions is a census of hospitals in Japan, conducted every 3 years. The survey data contains structural information such as the number of beds, the number of full-time employed physicians, and the number of nurses in full-time equivalent. We linked the data to the DPC database using hospital identifiers as a linkage key. Because of the anonymous nature of the data, the requirement for informed consent was waived. Study approval was obtained from the Institutional Review Board in the University of Occupational and Environmental Health.

Patient selection

We identified patients who had undergone elective cancer surgery including (i) lung lobectomy for lung cancer (excluding pneumonectomy), (ii) esophagectomy for esophageal cancer, (iii) gastrectomy for gastric cancer, (iv) colorectal cancer surgery (including colectomy for colon cancer and anterior resection or abdominoperineal resection for rectal cancer), (v) hepatectomy for hepatic cancer, or (vi) pancreatectomy for pancreatic cancer. These six surgeries are major oncological surgeries, which generally have a higher operative mortality than other procedures in general and thoracic surgery [3-5]. Those who underwent two or more cancer surgeries during one hospitalization were excluded.

Preoperative comorbidities included diabetes mellitus (ICD 10 codes, E10-E14), hypertension (I10-I15), cardiac diseases (I20-I25, ischemic heart diseases; I30-I52, other forms of heart diseases), cerebrovascular disease (I60-I69), chronic lung diseases (J40-J47), liver cirrhosis (K74), and chronic renal failure (N18). Based on Quan's protocol [22], each ICD-10 code of comorbidity was converted into a score, and was summed up for each patient to calculate a Charlson Comorbidity Index (CCI).

Professional staffing and hospital volume

In Japan, there are two types of nursing licenses, including a registered nurse and practical nurse, but there is no

mid-level provider's license, such as a physician assistant or nurse practitioner. Using the Survey of Medical Institutions data, we estimated the number of physicians per 100 beds (physician-to-bed ratio, PBR) and the number of nurses per 100 beds (nurse-to-bed ratio, NBR) for each hospital. Our data included the number of all the full-time employed physicians, including residents and attending physicians. The number of nurses included the full-time equivalent numbers of all the licensed nurses, but did not include the number of non-licensed providers, such as nurse aids. PBR and NBR are considered to be correlated and the problem of multicollinearity could occur if these two continuous variables were included in a multivariate model. To avoid this problem, PBR and NBR were combined into a single categorical variable including the following four groups: (i) Group A (*below* median PBR and *below* median NBR), (ii) Group B (*below* median PBR and *above* median NBR), (iii) Group C (*above* median PBR and *below* median NBR), and (iv) Group D (*above* median PBR and *above* median NBR).

Hospital volume was defined as the number of each surgical procedure performed annually at each hospital, and was categorized into tertiles (low-, medium-, and high-volume), with approximately equal numbers of patients in each group.

Outcomes

The outcome measurements included postoperative complications, inhospital mortality and failure to rescue (FTR). Postoperative complications included surgical site infection (T793, T814), peritonitis (K65), sepsis (A40, A41), respiratory complications (pneumonia [J12-J18], postprocedural respiratory disorders [J95] or respiratory failure [J96]), pulmonary embolism (I26), cardiac events (acute coronary events [I21-I24] or heart failure [I50]), stroke (cerebral infarction or hemorrhage [I60-I64]), and acute renal failure (N17).

FTR was defined as the proportion of inhospital death cases among those who had experienced a postoperative complication [18,19]. Therefore, FTR identifies whether the patient is successfully rescued from the complication. An underlying assumption of the FTR theory is that complications reflect patient severity, and the rescue of patients with complications depends on quick identification and aggressive treatment of complications [18,19]. There is ongoing controversy on how FTR should be calculated, because previous FTR studies have used different sets of complications. Silber's original FTR used a comprehensive set of complications, but several modified FTRs have used limited definitions. For example, a "nurse sensitive" definition only included six complications (pneumonia, shock, gastrointestinal bleeding, cardiac arrest, sepsis and deep venous thrombosis) [18]. Our original set of complications comprised common complications in general and thoracic surgery. We excluded rare complications in general and thoracic surgery, which were involved in Silber's definition, such as gangrene, amputation, decubitus ulcers, orthopedic complications and compartment syndromes.

Data analyses

Patient characteristics were summarized by four categories of physician/nurse staffing. We performed univariate comparisons of explanatory variables using a χ^2 test or an analysis of variance as appropriate. Inhospital mortality, postoperative complication rates, and FTRs were compared across physician/nurse staffing categories. Multivariate analyses were then performed to model the concurrent effects of potentially influential factors (age, sex, CCI, hospital volume, and physician/nurse staffing) on the outcomes using multi-level logistic regression analyses. Data were structured hierarchically into two levels: hospitals and patients. We accounted for clustering of outcomes within hospitals using mixed effects models. This approach is commonly used instead of basic regression approaches because outcomes of patients in the same hospital may be correlated, thus violating independence assumptions made by traditional regression procedures [23,24]. The threshold for significance was a p value <0.05. All statistical analyses were conducted using SAS ver. 9.2 (SAS Institute, Cary, NC, US).

Results

A total of 131,394 eligible patients were identified. Hospital volume categories (low, medium and high) were determined to be ≤51, 52–106, and ≥107 per year for lung lobectomy (n = 21,639); ≤9, 10–26, and ≥27 for esophagectomy (n = 3,917); ≤47, 48–93, and ≥94 for gastrectomy (n = 35,978); ≤66, 67–119, and ≥120 for colorectal surgery (n = 51,878); ≤22, 23–58, and ≥59 for hepatectomy (n = 10,921); and ≤13, 14–29, and ≥30 for pancreatectomy (n = 7,061).

Table 1 shows that the proportions of patients in the low-, medium- and high-volume groups were almost equal (33.6%, 33.0% and 33.4%, respectively). Lower volume hospitals were more likely to have a lower PBR and NBR. The median PBR was 19.7 (interquartile range, 14.6–27.3) per 100 beds and the median NBR was 77.0 (68.2–86.1) per 100 beds. These numbers were used as cutoff points to categorize physician/nurse staffing into four categories. The mean age was highest in Group A. Patients in Groups C and D had higher rates of several comorbidities. Consequently, CCI was higher among patients in Groups C and D than in those in Groups A and B.

Overall, postoperative complications were observed among 3.8% of patients for surgical site infection, 3.1%

Table 1 Patient characteristics

	Total	Group A: low PBR, low NBR	Group B: low PBR, high NBR	Group C: high PBR, low NBR	Group D: high PBR, high NBR	p
Number of patients	131,394	44,758	21,705	22,837	42,094	
Age (average ± SD, years)	67.8 ± 11.5	69.0 ± 11.0	68.4 ± 11.2	66.5 ± 11.8	66.8 ± 11.7	<0.001
Sex (males,%)	62.8	62.4	62.1	62.9	63.5	0.001
Preoperative comorbidities (%)						
Hypertension	17.5	16.2	15.9	19.2	18.7	<0.001
Diabetes mellitus	13.6	13.1	12.6	14.4	14.3	<0.001
Cardiovascular diseases	94.0	94.3	94.7	94.0	93.1	<0.001
Chronic lung diseases	4.9	4.1	3.9	5.2	6.1	<0.001
Liver cirrhosis	1.6	1.2	1.3	2.0	1.8	<0.001
Chronic renal failure	0.70	0.71	0.58	0.80	0.71	0.055
Cerebrovascular diseases	0.48	0.55	0.43	0.43	0.47	0.061
Charlson Comorbidity Index (%)						
0-2	61.2	64.3	63.4	59.2	57.8	<0.001
3-5	26.6	24.2	24.6	27.9	29.5	
6-	12.2	11.5	12.0	12.9	12.7	
Hospital volume						
Low	33.6%	58.2%	37.0%	16.3%	15.1%	<0.001
Medium	33.0%	27.0%	37.4%	35.1%	36.0%	
High	33.4%	14.8%	25.6%	48.6%	49.0%	

PBR, physician-to bed ratio (low, <19.7 physicians per 100 beds; high, ≥19.7); NBR, nurse-to-bed ratio (low, <77.0 nurses per 100 beds; high, ≥77.0).

for sepsis, 3.1% for respiratory complications, 2.6% for peritonitis, 1.9% for cardiac events, 1.0% for acute renal failure, 0.86% for stroke, and 0.20% for pulmonary embolism. In total, 15.2% of all patients had at least one complication. Overall inhospital mortality was 1.8% and the FTR rate was 11.9%.

Figure 1 illustrates the rates of inhospital mortality, postoperative complications, and FTR by the four categories of physician/nurse staffing. Patients with a higher PBR showed lower morality, complication rates, and FTR rates.

Table 2 shows the results of logistic regression analysis for FTR. Even after adjustment for patients' conditions and hospital volume, FTR rates were significantly different between Groups A and D (odds ratio, 0.76 [95% confidence interval, 0.63–0.90]; p = 0.002), but not between

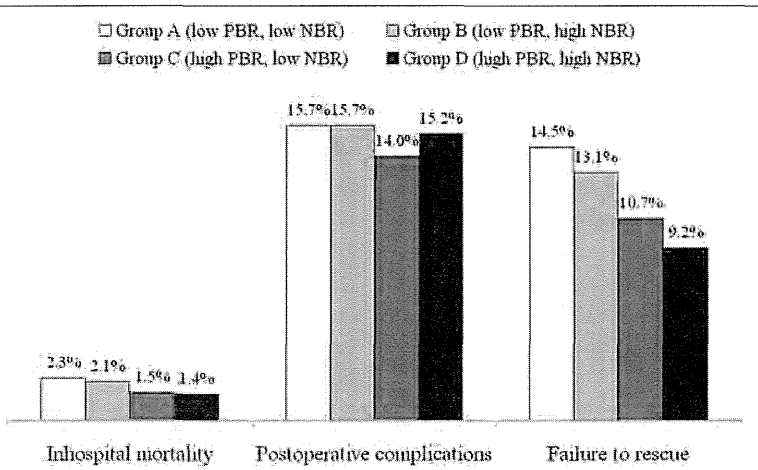

Figure 1 Relationship between physician/nurse staffing and cancer surgical outcomes. PBR, physician-to bed ratio (low, <19.7 physicians per 100 beds; high, ≥19.7); NBR, nurse-to-bed ratio (low, <77.0 nurses per 100 beds; high, ≥77.0).

Table 2 Logistic regression analysis for failure to rescue

	odds ratio	95% confidence interval			p
Age (10-year age increase)	1.50	1.43	-	1.57	<0.001
Sex (Female vs. male)	0.79	0.72	-	0.88	<0.001
Charlson Comorbidity Index	1.03	1.01	-	1.05	0.002
Hospital volume					
Low	1.00				
Medium	0.89	0.79	-	1.01	0.077
High	0.62	0.53	-	0.73	<0.001
Physician and nurse staffing					
Group A (low PBR, low NBR)	1.00				
Group B (low PBR, high NBR)	0.94	0.78	-	1.13	0.505
Group C (high PBR, low NBR)	0.91	0.73	-	1.13	0.379
Group D (high PBR, high NBR)	0.76	0.63	-	0.90	0.002

PBR, physician-to bed ratio (low, <19.7 physicians per 100 beds; high, ≥19.7); NBR, nurse-to-bed ratio (low, <77.0 nurses per 100 beds; high, ≥77.0).

Groups A and B (0.94 [0.78–1.13]; p = 0.505) or between Groups A and C (0.91 [0.73–1.13]; p = 0.379). Group D showed a relatively lower FTR rate than Group C, but this was not significant (0.83 [0.66–1.05]; p = 0.128).

When we conducted a similar analysis on inhospital mortality, Group D showed a significantly lower mortality compared with Group A (0.82 [0.71–0.95]; p = 0.009), while postoperative complication rates were not different among the groups (1.01 [0.90–1.13]; p = 0.918 for Group D vs. Group A).

Table 3 shows the results of post-hoc analyses of FTR rates in the four physician/nurse staffing groups by the types of surgery. FTR was significantly related to physician/nurse staffing in lung lobectomy, esophagectomy, gastrectomy, colorectal surgery, and pancreatectomy.

Discussion

The present study examined the association between cancer surgical outcomes and physician/nurse staffing in relation to hospital volume, using a nationwide administrative database. After adjustment for hospital volume, the FTR rate in the high-PBR-high-NBR group was significantly lower than that in the low-PBR-low-NBR group.

The inverse relationship between better professional staffing and hospital mortality in the present study is consistent with findings in previous studies [10-16]. Few studies have taken into account both professional staffing and hospital volume to evaluate surgical outcomes [13]. Our study revealed that better physician and nurse staffing were independently associated with a lower FTR in general and thoracic cancer surgery, irrespective of hospital volume.

Previously reported volume-outcome relationships may be partly explained by professional staffing. In this context, recent debate on hospital volume as an indicator of quality of care needs careful reconsideration in terms of allocation of a suitable number of qualified physicians and nurses as a structural basis for quality of care.

Volume-outcome relationships have mainly been explained by the "practice-makes-perfect" theory, and case accumulation has been enhanced based on this theory. In fact, growing interest in these relationships has bolstered relevant policy changes, including migration of cancer surgery to high-volume hospitals [25,26]. However, there is ongoing controversy regarding such policy; if patients are directed to higher volume institutions, the increased volume will overwhelm the resources of such institutions, thereby rendering these procedures even less accessible [27].

In accordance with our results, case accumulation should be accompanied by a suitable increase in medical staff. Concentration of physicians and nurses is considered necessary for hospitals regardless of size and case volume.

Efficient resource allocation for improving cancer surgical management is a common healthcare policy issue in any advanced nation. Japan is facing a super-aged society and weakened economy, which threatens the sustainability of the publish health insurance system. Physician shortage is an unsolved problem in Japan;

Table 3 Failure to rescue in the four physician/nurse staffing groups for each surgery

	N	Inhospital mortality (%)	Postoperative complications(%)	FTR (%)					
				Total	Group A: low PBR, low NBR	Group B: low PBR, high NBR	Group C: high PBR, low NBR	Group D: high PBR, high NBR	p
Lung lobectomy	21,639	0.92	10.2	9.0	15.3	12.9	7.9	5.9	<0.001
Esophagectomy	3,917	4.14	26.3	15.7	21.8	18.7	10.9	13.8	0.001
Gastrectomy	35,978	1.43	13.1	10.9	13.8	10.9	10.7	7.3	<0.001
Colorectal surgery	51,878	2.06	15.8	13.0	14.2	14.3	12.2	10.6	<0.001
Hepatectomy	10,921	2.49	17.4	14.3	17.3	14.3	11.8	14.0	0.061
Pancreatectomy	7,061	2.48	27.8	8.9	12.5	9.0	7.6	6.6	0.001

PBR, physician-to bed ratio (low, <19.7 physicians per 100 beds; high, ≥19.7); NBR, nurse-to-bed ratio (low, <77.0 nurses per 100 beds; high, ≥77.0).

the number of surgeons (including general and thoracic surgeons) is gradually decreasing from 28,425 in 1996 to 26,995 in 2008 [28]. Geographically, 2,522 surgical centers are distributed to an inhabited area of 121,000 km^2 in Japan (2.1 centers/100 km^2), as of 2008. A total of 44,010 cancer surgeries were performed in September 2008, and the mean number of cancer surgeries was calculated to be only 17.5 per hospital per month [2]. Therefore, healthcare resource allocation regarding cancer surgery in Japan is characterized as a large number of small hospitals with low case volume.

Based on our results, we speculate that consolidation of surgical centers and simultaneous reallocation of human resources could lead to better outcomes after cancer surgery, particularly in general and thoracic surgery. Migration of medical professions to high volume hospitals is considered essential. This approach should be implemented through the shutdown of low-volume surgical units, even if it will result in increased travel distance for cancer patients.

The Japanese Association of Thoracic Surgery has already initiated an attempt for regionalization of cardiac surgery by restricting its certification criteria for training institutions in 2005. This restriction has required several certified centers in the same regions to consolidate, resulting in an improvement in outcome and a slight decrease in accessibility to cardiac surgeries [29]. Unlike cardiac surgery, most cancer surgeries are elective; therefore, increased patient travel distance for cancer surgery could have less negative effect on health outcomes. Therefore, consolidation of cancer surgical centers may lead to improvement of outcomes that could compensate for a decreased accessibility to surgical care.

Several limitations should be acknowledged. First, we used the number of physicians per bed as an indicator for intensity of physician services, but further knowledge of individual physician characteristics, such as surgeon volume and training status (residents/fellows/board-certified physicians), and nurse characteristics, such as nurse education and the nurse work environment [14] could refine our approach. Second, other important outcomes including recurrence, long-term survival, and subsequent health resource consumption were not investigated in the present study because of data availability. Third, hospitals in the DPC database are not representative of all hospitals in Japan. Specifically, a low participation rate of very small hospitals in the DPC system skews the population being evaluated, and this might have resulted in underestimation of overall mortality. Fourth, the DPC database is an administrative claim database, and recorded diagnoses in such databases are less well validated than those in planned prospective cohorts or registries. Postoperative complications might have been underestimated due to underreporting. Because the DPC database includes only inpatient data, 30-day mortality was not available. Lastly, due to a novel author-derived definition of FTR, results may not compare directly with previously-published work.

Conclusion

Well-staffed hospitals confer a benefit for patients in terms of reduced FTR. Our results suggest that consolidation of surgical centers together with a concentrated allocation of medical professionals may improve the quality of surgical care for cancer.

Competing interests
The authors have no competing interests.

Acknowledgements
This study was funded by a Grants-in-Aid for Research on Policy Planning and Evaluation (H22-Policy-031 and, in part, H22-Policy-033) from the Ministry of Health, Labour and Welfare, Japan, by a Grant-in-Aid for Scientific Research B (No. 22390131) from the Ministry of Education, Culture, Sports, Science and Technology, and by the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST program) from the Council for Science and Technology Policy, Japan (No. 0301002001001). The Survey of Medical Institutions data use was approved by the Statistical Bureau, the Ministry of Health, Labour and Welfare, 17 August 2010 (No. 0817–6).

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Authors' contributions
HY and HH1 conceived the study concept and study design. HY and HH2 performed compilation and synthesis of the data. HY and HM carried out statistical analyses. SM supervised the DPC research project. All authors participated in interpretation of the results and writing of the report, and approved the final version.

Received: 20 July 2011 Accepted: 28 May 2012
Published: 28 May 2012

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doi:10.1186/1472-6963-12-129
Cite this article as: Yasunaga *et al.*: Variation in cancer surgical outcomes associated with physician and nurse staffing: a retrospective observational study using the Japanese Diagnosis Procedure Combination Database. *BMC Health Services Research* 2012 **12**:129.