Disparities in Mortality among Doctors in Taiwan: A 17-year follow-up study of 37,545 Doctors

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Disparities in Mortality among Doctors in Taiwan:

A 17-year follow-up study of 37,545 Doctors

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Objectives. We used cohort data from the registry of all doctors in Taiwan to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Design. Retrospective cohort study, 1990-2006.

Settings. The Taiwan Medical Association (TMA).

Participants. A total of 37,545 doctors from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors.

Main outcome measures. Cause-specific standardized mortality ratios (SMRs) for surgeons and anesthesiologists were compared to those of the internists. Cox's proportional hazard model was constructed to explore multiple risk factors for mortality, including specialties, age, gender, geographic region of practices, regional health resources, ages of beginning practices, and years of beginning practice.

Results. The all-cause specific SMRs for surgeons and anesthesiologists were marginally elevated at 1.15 (95% confidence interval: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64) respectively. The Cox regression model showed that the anesthesiologists had the highest hazard ratio (HR) of 1.97, seconded by surgeons at 1.23. Localities with the doctor to population ratio lower than 1:500 were associated with an increased HR of doctor mortality.

Conclusions. The doctor to population ratio and the region of practice may influence doctor's mortality. Increasing number of doctors and/or improving the practice environment may be helpful in reducing the health disparities in regions with poor resources.

Article Summary

Article focus

To determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Key messages

- All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.
- Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Strengths and limitations of this study

Strengths

- The cohort data includes all practicing doctors in Taiwan.
- We use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states.

Limitations

- Possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties.
- Information was limited about the hospital level and location practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting.

During practices, health care providers have already been noted to suffer from certain specific potential hazards like stress, radiation, anesthetic gases or agents and biologically hazardous blood or body fluids, which have been documented in many previous studies among radiologists, pathologists, psychiatrists, dentists, and anesthesiologists[1-6].

Beginning in 1995, Taiwan launched the National Health Insurance (NHI) program and attempted to mitigate the health disparity among the general population living in different geographic regions. The provision of universal health care coverage has increased the health care demand[7-8]. For example, the number of outpatient visits per person increased from 10.56 in 1995 to 14.88 in 2008, and the numbers of hospitalized patients and outpatient visits per doctor increased as well[9-10]. , Thus, all the healthcare professionals, including doctors, have encountered a heavier workload and a greater psychosocial demand than before. However, a standardized mortality ratio (SMR) study using the general population as the reference for comparison did not detect any increased mortality among doctors in Taiwan[11].

From an alternative perspective, the association between demographic characteristics of human resources in health and the health of the population served has received considerable attention[12-13]. There is a growing evidence that the density of the health workforce is directly correlated with positive health outcomes in the population they serve, such as maternity mortality, infant mortality and life expectancy[14]. Other factors like geographic location, socioeconomic states and distribution of current health care resources might also affect health outcome and incline to inter-correlate with each other.

As all factors leading to health disparities are affecting people within respective locality[15], we hypothesized that they also influence the mortality rates of healthcare providers, including doctors who practiced in such locality. In the present study, we

used the cohort data from the registry of the doctor file maintained by the Taiwan Medical Association (TMA) and recruited internists, the largest group, as referents to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Methods

Subjects and data collection

The retrospective cohort was established from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. It contains the name of each individual, date and place of birth, gender, national identification number, medical school attended, date of graduation, self-designated specialty, place of practice, vital status, date of death for decedents, and date of ceasing the membership. The cohort was established beginning in January 1990 and followed up to December 2006. Practice time was accrued until 2006, or the date of deceased or termination of membership. There were 29 decedents with incomplete information on date or month of death, of which this study assumed to be on the first day of the month or year. Since all practicing doctors must be registered in compliance to the Doctors Act in Taiwan, the dataset is very comprehensive and accurate.

Statistical analysis

Geographic data in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth were collected and analyzed from national statistics of the Directorate General of Budget, Accounting and Statistics (Taiwan) in 1998, 2002, and 2006. Geographic region was categorized into northern, central, southern and eastern region following the naming of branches of Bureau of National Health Insurance. Education indicated the percentage of people aged more than 15 who attained an education level of college or above.

All-cause and cause-specific standardized mortality ratios (SMRs) were obtained by employing the personal computer version of Life Table Analysis System (LTAS.NET). The LTAS was originally developed by the National Institute for

Occupational Safety and Health (NIOSH) during the 1970s and was later converted for use on Windows 98/NT/2000/XP-compatible PCs. This program tabulates the underlying causes of death as well as the person-years of follow-up into age-, gender-, and race-specific strata, and allows users to apply internal controls as referents to replace general population from vital statistics. SMRs and 95% confidence intervals (CIs) were calculated using the mortality rates of 119 underlying causes of death of the internists of Taiwan as the reference group. We used SAS Version 9.1 (SAS institute) to edit and analyze the data. In this study, we set the significance level at p=0.05.

Cox regression analysis was conducted to determine the hazard ratios for the following risk factors: age, gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice (before or after 1995 when the NHI system was established), and doctor to population ratio. The ratio between doctors and population was categorized into 4 levels: larger than 1:500, from 1:500 to 1:700, from 1:700 to 1:900, and less than 1:900. Since the northern region of Taiwan leads development for the last half a century, it was chosen to be the reference in the statistical model. The covariates considered in the regression analysis were gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice, and doctor to population ratio. We applied the stepwise strategy for variable selection with the significance level for entry and the significance level for stay set to 0.15. Regression diagnostics were also run, including examination of proportional hazard assumption, residual analysis, detection of influential cases, and check for multi-co-linearity to assure the quality of analysis and goodness of fit for the model.

Results

With the doctor to population ratio above 1:500 as the reference level, we found that a lower ratio significantly increased the hazard ratio (HR) of doctor mortality; there was also an independent effect of regional difference of higher HR for southern and eastern regions, as summarized in Table 4. The differences among localities seemed to correlate well with higher average levels of income and education, lower infant mortality rates, and longer life expectancies across Taiwan. And such disparities did not appear to have changed during the last decade (Table 1).

A total of 37,545 doctors were tabulated in the study from January 1990 to December 2006. During the above period, there were 1642 deaths among 32,713 male doctors and 44 deaths among 4822 female doctors. The overall mean age at death was 69.88± 14.28 years old, with 70.06±14.04 for males and 62.96±20.21 for females, respectively. (Table 2) Approximately half (49.7%) of the cohort had been internists, 48.1% were practicing in the north region. Among all doctors, there were 30.8% working in the area of low doctor to population ratio. About two-thirds began their practice before 1995, and over 90% started practice at age below 40.

As for the control for socioeconomic status in the analysis, we used the internists as the reference population and found that the all cause specific SMRs for surgeons and anesthesiologists were marginally elevated with an SMR of 1.15 (95% CI: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64), respectively (Table 3). Among the surgeons, the SMR of "Neoplasm of lymphatic and hematopoietic tissue" was increased but without statistical significance (SMR = 2.17, 95% CI: 0.94 to 4.28). The observed numbers of deaths from malignant neoplasm of digestive organs and peritoneum were significantly lower than corresponding expected values (SMR =0.54, $p < 0.05$, 95% CI: 0.29 to 0.92). Among the anesthesiologists, the SMR of "malignant neoplasm of other and unspecified sites" was significantly increased (SMR =8.73, $p < 0.05$, 95%

CI: 1.06 to 31.53), although there were only 2 cases on the observed number.

To further adjust for other risk factors, the Cox regression model was constructed and the results were summarized in Table 4. The anesthesiologists appeared to show the highest hazard ratios (HRs) of 1.97 (95% CI, 1.20 to 3.25), followed by surgeons with a HR of 1.23 (95%CI, 1.04 to 1.46). The HR of ophthalmologists was significantly lower than all other specialists, of which the HR was 0.72 (95%CI, 0.53 to 0.98). In addition, doctors living in the northern region and the central region experienced lower HR's. And doctors who worked in the area with doctor to population ratio below 1:500 showed higher mortality or HR.

The doctors who began practice at an older age had a higher HR of 1.12 (95%CI, 1.12 to 1.13) for every single year increment. Overall, doctors who began practice after the implementation of NHI Program, or the year of 1995, showed a higher HR of 6.17 (95%CI, 4.27 to 8.92).

Discussion

Based on Cox's Model analysis, we found doctors practicing in southern and eastern regions of Taiwan suffered from statistically significant premature mortality (Table 4), and such a geographic disparity appeared to correspond to the lower life expectancy and higher infant mortality rate in Taiwan (Table 1). To our limited knowledge, this study is the first to show that doctors practicing in the area of a low doctor to population ratio or in the less resourceful regions experienced a higher HR of mortality after adjustment for gender, age of beginning practice, and specialties (Table 4). Since the study is conducted exclusively among doctors with the same socioeconomic status, it raises the question whether the other two main factors, occupational workload or practice environment, may have played an important role.

Lowest average income, educational level and life expectancy, and the highest infant mortality rate in Taiwan were found in the eastern region (Table 1). Traditionally, this mountainous region impedes transportation tremendously, and plays a significant role in reduced healthcare accessibility for people, including health care providers themselves. Although the doctor to population ratio has improved since the promulgation of Medical Care Act in 1986 and implementation of NHI in 1995, doctors living in this region still suffer from a higher HR. It may indicate that the health disparity still exists. Moreover, in analyzing the central and southern regions, where similar levels of the average income and the education were found, a significantly increased hazard ratio was detected in the southern region only. As noted in Table 1, the doctor to population ratio has been consistently found to be lower in the southern region compared with those of the northern and central regions. These findings indicate persistent health disparities in different regions of Taiwan, and suggest that occupational workloads might play some role in view of the increased mortality of doctors.

In a previous study, we found that the overall and cause-specific SMRs of doctors in Taiwan were less than 0.34 for different specialties[11], which may have been confounded by using the general population as the referents for comparison[16]. In this study, we use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states (Table 3). Although no increased mortality was found among radiologists, pathologists, and psychiatrists, as reported from other countries[2-4], we detected significantly increased HRs for surgeons and anesthesiologists (Table 4). A further analysis only detected slightly elevated SMR for malignant neoplasm of lymphatic and hematopoietic tissues among surgeons, which appeared to corroborate the hazards of operation room reported by others[17]. However, the trend was less apparent because of the small sample size of anesthesiologists. Since the current mortality data in Taiwan only allowed for coding single underlying cause of death, it may further decrease the power of detection of occupational related illnesses.

Our study also demonstrated the HR of mortality was higher in the group beginning their practice since 1995, when the National Health Insurance system was implemented. This group belonged to a younger generation of doctors, who might possibly suffer from highly stressed work during their practice[18]. Such a stress might arise from their clinical training program or the newly implemented health policy. However, the cohort was established during 1990-2006, which may have imposed a selection of healthy survivors among the doctors. They began their practice before 1995 in comparison with those who entered the workforce after 1995. Thus, more study is needed to explore the above hypothesis.

Several limitations of this study should be noted. Firstly, possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties. For instance, a surgeon shifted to general practice after retiring from a medical center may result in overestimation of the practice duration and possible underestimation of the effect of specialty. Thus, the higher HR’s among surgeons and anesthesiologists may need to be further studied for clarification. Secondly, information was limited about the hospital level and location practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

In conclusion, disparities both in the geographic region of doctor's practice and the ratio of doctor to population regionally are the primary determinants to the HR of doctor mortality. Thus, we recommend increasing the number of doctors and improving the practice environment of eastern and southern regions of Taiwan, which may possibly mitigate the health disparities among doctors and people. Further, more studies are needed to explore and reduce the potential hazards among workplaces of anesthesiologists and surgeons in Taiwan.

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Contribution statement

The first author, Dr. Tung-Fu Shang, has written the first draft, full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. And, Dr. Pau-Chung Chen has reviewed the data and dealt with statistics. Dr. Jung-Der Wang is the guarantor.

Competing interests:

All authors of this manuscript indicate no conflicts of interest and have complied with the Principles of Ethical Practice of Public Health.

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Table 1 -- Geographic disparities in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth in 1998, 2002, and 2006.

Region	Doctors per 10,000 persons			Per capita disposable income			Education [§]			Infant mortality rate			Life expectancy		
	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006
Northern	14.7	16.5	17.4	8394.8	8912.6	9853.0	24.8	30.1	36.1	6.2	4.9	4.4	77.4	78.6	79.5
Central	14.1	16.5	18.3	7044.2	6940.0	7817.6	18.8	23.2	28.6	6.9	5.8	4.5	75.1	77.0	77.6
Southern	12.9	14.5	16.5	6928.8	7157.5	7891.2	18.4	22.8	27.7	6.4	5.4	4.8	74.7	76.0	76.5
Eastern	13.3	15.4	18.3	6542.2	6683.0	7987.6	11.8	14.4	20.0	12.4	8.3	7.6	70.6	72.9	73.2

[§]**Education**: The percentage of people aged more than 15 attained an education level of college or above

Table 2 -- Characteristics of Taiwan doctors included in the study from 1990 to 2006.

	Taiwan doctors		Deceased doctors	
	No. (%)	mean censored age	No. (%)	mean age at death
Total	37,545 (100)	46.41±14.47	1686 (100)	69.88±14.28
Status				
Alive	35,859 (95.5)	45.31±13.51		
Deceased	1686 (4.5)			69.88±14.28
Sex				
Male	32,722 (87.2)	47.68±14.56	1642 (97.4)	70.06±14.04
Female	4823 (12.8)	37.81±10.30	44 (2.6)	62.96±20.21
Age of beginning practice				
age<30	29,753 (79.2)	43.39±11.99	566 (33.6)	59.03±14.98
30<=age<40	5573 (14.8)	52.28±14.10	472 (28.0)	73.81±11.92
age≧40	2219 (5.9)	74.24±10.91	648 (38.4)	76.37±8.62
Specialty				
Surgeon	4571 (12.2)	45.20±13.20	161 (9.5)	65.83±14.54
Internist	18,664 (49.7)	48.76±15.97	1190 (70.1)	71.92±12.70
Dermatologist	901 (2.4)	43.00±12.92	35 (2.1)	69.79±16.25
Otolaryngologist	2000 (5.3)	44.28±11.99	45 (2.7)	65.46±14.36
Ophthalmologist	1584 (4.2)	44.72±12.33	42 (2.5)	72.28±19.56
Pathologist	414 (1.1)	42.21±12.04	5 (0.3)	49.78±10.87

Pediatrician	2883 (7.7)	42.35±11.59	54 (3.2)	66.32±17.12
Psychiatrist	1214 (3.2)	40.37±11.81	21 (1.2)	61.85±20.52
Radiologist	1076 (2.9)	41.59±11.79	18 (1.1)	63.23±18.18
Obstetrician	2278 (6.1)	48.84±12.10	85 (5.0)	63.48±14.44
Orthopedist	1128 (3.0)	43.56±11.07	14 (0.8)	58.78±18.32
Anesthesiologist	832 (2.2)	40.91±10.23	16 (0.9)	45.21±15.67
Region				
Northern	18,046 (48.1)	45.71±14.52	659 (39.1)	68.90±14.32
Central	7054 (18.8)	46.25±13.70	300 (17.8)	70.04±15.58
Southern	11,376 (30.3)	47.64±14.81	667 (39.6)	70.97±13.57
Eastern	1069 (2.8)	46.24±14.12	60 (3.6)	67.67±13.96
Doctor-population ratio				
＞1：500	17,185 (45.8)	45.29±14.34	620 (36.8)	68.21±15.11
1：700 to 1：500	6429 (17.1)	45.55±14.50	285 (16.9)	69.71±14.19
1：900 to 1：700	11,233 (29.9)	47.91±14.21	589 (34.9)	70.92±13.61
＜1：900	2698 (7.2)	51.08±14.53	192 (11.4)	71.90±13.02
Years of practice				
Before 1995	24,337 (64.8)	53.62±12.71	1640 (97.3)	70.60±13.52
After 1995	13,208 (35.2)	33.13±5.06	46 (2.7)	44.28±16.86

Table 3 -- The observed number of deaths and cause specific SMRs (standardized mortality ratios) for surgeons and anesthesiologists, using internists of Taiwan as the reference group.

	Surgeon			Anesthesiologist		
Causes of death	**O**	**SMR**	**95%CI** [§]	**O**	**SMR**	**95%CI**
All causes	161	1.15	(0.98 - 1.34)	16	1.62	(0.93 - 2.64)
All malignant neoplasm (MN)	37	0.84	(0.59 - 1.16)	5	1.57	(0.51 - 3.66)
MN of digestive organs and peritoneum	13	0.54	(0.29 -0.92)	2	1.18	(0.14 -4.26)
MN of respiratory system	11	1.16	(0.58 - 2.07)	0	0.00	(0.00- 6.56)
MN of urinary organs	2	1.05	(0.13 - 3.79)	0	0.00	(0.00 - 20.42)
Neoplasm of lymphatic and hematopoietic tissue	8	2.17	(0.94 - 4.28)	1	3.41	(0.09 -19.03)
MN of other and unspecified sites	1	0.48	(0.01 -2.68)	2	8.73	(1.06 - 31.53)
Cerebrovascular disease	7	0.59	(0.24 - 1.22)	3	3.95	(0.82 - 11.55)
Heart disease	9	0.83	(0.38 -1.57)	0	0.00	(0.00 - 7.34)
Accidents	11	1.81	(0.90 -3.24)	1	1.58	(0.04 - 8.79)
Diabetes mellitus	8	1.49	(0.65 -2.94)	1	1.84	(0.05 -10.25)
Chronic liver disease	7	1.60	(0.64 -3.30)	0	0.00	(0.00 -13.75)
Kidney disease	1	0.36	(0.01 -2.01)	0	0.00	(0.00 -21.26)
Pneumonia	5	0.97	(0.32 - 2.27)	0	0.00	(0.00 -12.23)

Suicide	3	1.36	(0.28 - 3.98)	1	3.34	(0.08 -18.60)
Chronic lung disease	4	2.19	(0.60 - 5.60)	0	0.00	(0.00 -116.04)
Hypertensive disease	2	1.45	(0.18 - 5.25)	0	0.00	(0.00 - 30.76)

[§] CI: confidence interval

Table 4 -- Hazard ratios with 95% CI (confidence interval) estimated through Cox regression model to control relevant risk factors on mortality among Taiwan doctors from 1990 to 2006.

Covariate	Hazard ratio	95% CI
Age of beginning practice		
	1.12	1.12-1.13
Gender		
Female/male	0.76	0.56-1.02
Specialty		
Dermatologist / Internist	1.19	0.85-1.67
Otolaryngologist / Internist	0.85	0.63-1.15
Ophthalmologist / Internist	0.72	0.53-0.98
Pathologist/ Internist	0.81	0.33-1.94
Pediatrician / Internist	0.91	0.69-1.20
Psychiatrist / Internist	0.81	0.52-1.24
Radiologist / Internist	0.87	0.55-1.39
Surgeon / Internist	1.23	1.04-1.46
Obstetrician / Internist	1.19	0.95-1.50
Orthopedist / Internist	0.75	0.44-1.27
Anesthesiologists/ Internist	1.97	1.20-3.25
Region		
Central / Northern	1.12	0.97-1.29
Southern / Northern	1.30	1.17-1.45
Eastern / Northern	1.68	1.28-2.20

Doctor-population ratio		
1：700 to 1：500 / ＞1：500	1.23	1.06-1.42
1：900 to 1：700 / ＞1：500	1.20	1.06-1.34
＜1：900 / ＞1：500	1.18	1.00-1.39
Year of beginning practice		
After 1995/ Before1995	6.17	4.27-8.92

WHAT IS ALREADY KNOWN ON THIS TOPIC

All factors leading to health disparities are affecting people within respective locality.

WHAT THIS STUDY ADDS

All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.

Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			**4-5**
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			**6-7**
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			8-9

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9
		(*b*) Report category boundaries when continuous variables were categorized	8-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-9
Discussion			10-11
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-12
Other information			13
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Disparities in Mortality among Doctors in Taiwan: A 17-year follow-up study of 37,545 Doctors

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RESPONSE TO THE MANAGING EDITOR AND REVIEWERS

For the managing editor

From the managing editor:
Please ensure that all authors meet the ICMJE criteria: http://www.icmje.org/ethical_1author.html.
Any authors that do not meet these criteria should be incldued in the acknowledgements. For example Dr Jung-Der Wang is the 'guarantor' of the paper but does not appear to have been involved in the research.

Response: Thank you for your comment. It is probably out of some errors made in the process of submitting this manuscript that might have caused you misunderstanding. In fact, I have contributed to the study design, data analysis, and finalize the contents of the manuscript together with the first author, Dr. Shang and second author, Dr. Chen. To avoid confusion, I have revised the "Contribution statement" (page 14) as follows:

Contribution statement

The first author, Dr. Tung-Fu Shang, has acquired the dataset, designed the study together with Dr. Wang (the corresponding author), conducted the analysis under the full supervision and discussion with Drs. Chen and Wang, written the first draft, and all three participated in the revision of the later drafts until the final one.

Dr. Shang has access to all the data in the study and takes responsibility for the integrity of the data. Together with all co-authors, we shall be responsible for the accuracy of the data analysis, interpretation of the results.

For Reviewer

Comment # 1

My main objection is that a paper that presents geographic location as a possible cause of premature death among doctors does not discuss the possible causes of choosing a location, or moving from one location to another.

Response: The authors would like to thank the reviewer for your comment. The retrospective cohort was established from the registry of the doctor file maintained by TMA (Taiwan Medical Association). The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. The data only indicates the latest status on the date of December 31, 2006, or on the date of deceased or termination of membership. Although moving location of practice for doctors in Taiwan may not be very prevalent in general, we have included the limitation in the "Discussion" section as recommended by you in another comment as well. Please kindly see the revised paragraph as follows: (Please see page 13, ll. 7-11)

clarification. Secondly, information was limited by the hospital level and the locations which the doctor has ever practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

Comment # 2

The question of approval is unclear. The authors state that they all "have complied with the Principles of Ethical Practice of Public Health", but is this the same as approval?

Response: We would like to thank the reviewer for your comment. Yes, this study was approved by the Ethics Review Board of the National Taiwan University College of Public Health. For further clarification, please kindly see the revised "Competing interests" (page 14) as follows:

Competing interests:

All authors of this manuscript indicate no conflicts of interest and have complied with the Principles of Ethical Practice of Public Health. The Ethics Review Board of our institute (Institute of Occupational Medicine and Industrial Hygiene College of Public Health, National Taiwan University, Taiwan) approved the protocol before the commencement of this study.

Comment # 3

It might be useful to explore a possible convergence in mortality between doctors and other segments of the population, like we did in our study on Norwegian doctors (Aasland OG, Hem E, Haldorsen T. Ekeberg Ø. Mortality among Norwegian doctors. BMC Health Serv Res. 2011 Mar 22; 11 (1):173).

Response: The authors would like to thank the reviewer for the constructive comment, which advice us to prevent potential confounding from education and/or socioeconomic status by using other comparable segments of population. In Taiwan, doctors have much higher average earnings per month than all the other health professionals like nurses. It is different from a more socialist country like Norway. The relevant data can be found in The Labor Statistics Database of the International Labor Organization, as summarized below:

	Physician (Average earnings per month)	Professional nurse (Average earnings per month)	Physician vs Nurse
Taiwan	112,658 NT	35,461 NT	3.17
Norway	58,059 Krone	32,214 Krone	1.80

Source: The Labour Statistics Database of the International Labor Organization (1999-2008).

Moreover, since our previous study found that the overall and cause-specific SMRs (Standardized Mortality Ratios) of doctors of all different specialties in Taiwan were generally less than 0.30-0.34 in comparison with the general population (Reference # 11, Shang TF, et al. Mortality of Doctors in Taiwan, 1990-2006. Occup Med (Lond) 2011;61(1):29-32. in the manuscript), it would be very difficult for us to choose a much less confounded occupation as the referents for comparison. In fact, we have tried to adopt school teachers, professors, or other health professionals as the reference population. However, doctors could keep on practice without retirement in Taiwan due to our culture and the system of health care, which is dominated by private sectors (85% of the hospitals and 97% of the clinics) and no age limit in the reimbursement policy of the National Health Insurance. Thus, doctors often practice until a very old age, even up to 70-80 years old, while all other professional groups are required to retire before the age of 65-70 and their names are usually removed from the registries after retirement. The comparability of information would be a big problem and difficult to be tackled.

To prevent potential confounding by different socioeconomic status profession-related knowledge, health-related behaviour and different ages of retirement, we decided to use "internal comparison", namely, selecting internists who are of the biggest size as the reference population for SMR calculation in this study, instead of other segments of population. And time after practice is also considered as a risk factor to replace age because of co-linearity in the model construction. Thus, we have revised several sentences in the manuscript, as follows: (Please see page 11, ll. 9-14)

(Table 4). Because doctors in Taiwan generally have higher earnings than all other segments of professionals and there is no upper limit of retirement age, we have decided to select "internal comparisons" among doctors with the same socioeconomic status, profession-related knowledge and health-related behaviour, to prevent confounding and would leave the effects of mortality to the other two main factors, occupational workload or practice environment.

Comment # 4-1

Out-patient settings: Half of the doctor population in this study is categorized as internists. Since none of the categories are called family medicine or general practice, I assume that some of the internists are in effect general practitioners working outside hospitals, but such information is not given. One should think that "patient load", or doctor to population ratio, as a possible confounding variable for stress etc., is more important for doctors in outpatient settings? More information on the work pattern for doctors in Taiwan is needed! (See also point 5 below)

Response: Thanks for the constructive comment. In Taiwan, traditionally the family medicine (family doctor) or general practitioners used to be under the name of general medicine, which have been included in the internists group. In fact, we have a table detailing the definition for different specialties in our previous paper (Reference # 11, Shang TF, et al. Mortality of Doctors in Taiwan, 1990-2006. Occup Med (Lond) 2011;61(1):29-32. in the manuscript), which is shown as below for clarification:

Specialty	Individual Specialties
Surgeon	General surgery, Paediatric surgery, Plastic surgery,

	Cardiothoracic surgery, Traumatic surgery, Emergency surgery, Neurosurgery.
Internist	General medicine, Cardiology, Physical medicine, Nephrology, Endocrinology, Clinical genetics, Gastroenterology, Haematology, Oncology, Occupational medicine, Chest medicine, Neurology, Infectious disease, Epidemiology, Intensive care medicine, Forensic medicine,
Dermatologists	Dermatology,
Otolaryngologists	Ear nose throat surgery,
Ophthalmologists	Ophthalmology,
Pathologists	Clinical pathology, Pathology,
Paediatricians	Paediatric,
Psychiatrists	Psychiatry,
Radiologists	Nuclear medicine, Radiotherapy, Radiation oncology, Radiology,
Obstetricians	Obstetrics, Gynaecology,
Orthopaedists	Orthopaedics surgery,
Anaesthesiologists	Anaesthetics.

In addition to this above clarification, we also add Reference # 11in the "Methods" section as follows**:** (Please see page 6, ll. 6-9)

for verification of credentials of all practicing doctors. It contains the name of each individual, date and place of birth, gender, national identification number, medical school attended, date of graduation, self-designated specialty[11], place of practice, vital status, date of death for decedents, and date of ceasing the membership. The cohort

Comment # 4-2

Doctor mobility: In this study the present working location (by region) for each doctor is used as a predictor for mortality. In my own country doctors move around quite a bit, mainly from rural to urban areas, but also from urban to rural. The analyses in this study presuppose no such movements – is this realistic? And linked to this argument, why do some doctors choose rural and other urban areas, or different geographical locations in general? Can such reasons be causes of variation in health and mortality?

Response: Again, thank you for the comment. The retrospective cohort was established from the registry of the doctor file maintained by TMA (Taiwan Medical Association). The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. The data shows the latest status only on the date of December 31, 2006, or on the date of deceased or termination of membership.

As I mentioned in one of the earlier responses, the health care system of Taiwan is dominated by private sectors (85% of the hospitals and 97% of the clinics) and doctors have been allowed to select practicing location freely and enjoy a higher income by the universal coverage of compulsory national health insurance. While there may be moving of practicing locations, most doctors usually stay in a location for a long time because it generally takes several years to develop his/her regular clients in a community. However, we appreciate this comment and make following revision in the "Discussion" section as our response to the comment # 1: (Please see page 13, ll. 7-11)

clarification. Secondly, information was limited by the hospital level and the locations which the doctor has practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

Comment # 4-3

Cohort and age: A distinction is made between the doctors who started their practice before and after 1995, respectively. We are told that in 1995 a National Health Insurance System was implemented, and that the younger doctors, because of this (?), "might possibly suffer from highly stressed work during their practice" (page 11). The meaning of this is unclear: didn't also the older doctors, at least those still in practice, have to comply with the new insurance system? Also, "age for beginning practice" is used as the general age variable in the models. Why not use biological age?

Response: Thank you for your comment. Yes, both young and old doctors have been influenced by the establishment of the National Health Insurance program. However, most older doctors have already established their community practice, while young doctors would be more likely to have a higher stress during the initial stage of developing his/her clients in a community. Moreover, the cohort in our study was established during 1990-2006, which may have selected healthy survivors among the older doctor group in this registry.

The statistical analysis shows that the practicing duration is highly collinear to the biological age (i.e. age at censoring in the study). We chose the latter to be included in the final model, because there is no upper limit of retirement for doctors in Taiwan and doctors who are still practicing are generally healthier than those who retired. Moreover, the use of practicing time can be a more accurate measurement of workload and/or occupational exposure in terms of duration.

In our study, years of beginning practice were used as independent variables to control the potential confounding from a specific group. This group consists of doctors who practiced at an older age experienced higher HR of mortality. Most of them are veteran doctors who took ad-hoc medical mission during the world II and did not receive an academic medical education. Following your constructive advice, we have added this information in the Methods section to clarify for our future readers, as follows: (Please see page 7, ll. 19-23)

beginning practice, and doctor to population ratio. In Taiwan, some of our doctors were veteran who took ad-hoc medical missions during the world II and did not receive an academic medical education. They generally began their practices at an age older than most other doctors and deserved for this study to control as a potential confounder. We applied the stepwise strategy for variable selection with the

Comment # 4-4

Why are anesthesiologists always singled out? I am aware that there may exists an impression internationally that anesthesiologists have a higher mortality than other medical specialists, although the documentation for this is not very convincing (see e.g. the special issue of Acta Anaesthiol Scand from 2002 on this topic (p. 1183 ff)). The quote from Bruce et al. (# 17) describing ”the hazards of operation rooms” is 44 years old and hardly relevant today. I can not see the rationale for tabulating the 16 deaths among anesthesiologists across a large number of causes, as in table 3. Also, even if I understand that another publication (# 11) may have tabulated the differeneces between doctors and the general population in causes of death, I miss some of these comparative data in the present paper.

Response: Thanks. Although we had some hypotheses in mind before this study, the condition in Taiwan might not necessarily be the same as previous reports. Thus, we used the national cohort data to analyze the mortality risks or hazard ratios (HRs) for all formally registered specialties tabulated above (response to the comment # 4-1), including radiologists, pathologists, psychiatrists, dentists, surgeon and anesthesiologists, etc. And we consistently detected significantly increased HRs for surgeons and anesthesiologists. Hence, we would like to know whether any specific diseases would happen among these two specialties who were well known to be exposed to the hazards of operation rooms and the results have been showed in Table 3.

Comment # 4-5

Internists as reference: The large – and possibly quite heterogeneous – group of internists is used as reference throughout the paper. Is this optimal? Wouldn't the contrasts be clearer if one of the smaller more homogeneous groups were used, e.g. the surgeons? And where are the family doctors?

Response: Thank you again for your comment. To achieve maximal statistical efficiency, we had better select a reference group with a sufficient size of subjects and take the advantage of employing the software of Life Table Analysis System (LTAS) produced by the U.S. NIOSH (National Institute of Occupational Safety and Health) to calculate the standardized mortality ratios (SMRs). This software tabulates the underlying causes of death as well as the person-year of follow-up into age-, gender-, and race-specific strata. Therefore, since there are 18,664 internists as contrast to 4,571 surgeons, we use the largest number of referents to detect potential hazards for other subspecialties, as our study in the reference No. 11 has indicated that there were small variations of SMR's among different specialties of doctors. Please also kindly refer to the table included in our response to the Comment # 4-1 for the definitions of family doctors (family medicine), general practitioners, or general medicine in Taiwan.

Disparities in Mortality among Doctors in Taiwan:

A 17-year follow-up study of 37,545 Doctors

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Objectives. We used cohort data from the registry of all doctors in Taiwan to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Design. Retrospective cohort study, 1990-2006.

Settings. The Taiwan Medical Association (TMA).

Participants. A total of 37,545 doctors from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors.

Main outcome measures. Cause-specific standardized mortality ratios (SMRs) for surgeons and anesthesiologists were compared to those of the internists. Cox's proportional hazard model was constructed to explore multiple risk factors for mortality, including specialties, age, gender, geographic region of practices, regional health resources, ages of beginning practices, and years of beginning practice.

Results. The all-cause specific SMRs for surgeons and anesthesiologists were marginally elevated at 1.15 (95% confidence interval: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64) respectively. The Cox regression model showed that the anesthesiologists had the highest hazard ratio (HR) of 1.97, seconded by surgeons at 1.23. Localities with the doctor to population ratio lower than 1:500 were associated with an increased HR of doctor mortality.

Conclusions. The doctor to population ratio and the region of practice may influence doctor's mortality. Increasing number of doctors and/or improving the practice environment may be helpful in reducing the health disparities in regions with poor resources.

Article Summary

Article focus

To determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Key messages

- All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.
- Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Strengths and limitations of this study

Strengths

- The cohort data includes all practicing doctors in Taiwan.
- We use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states.

Limitations

- Possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties.
- Information was limited about the hospital level and location practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting.

During practices, health care providers have already been noted to suffer from certain specific potential hazards like stress, radiation, anesthetic gases or agents and biologically hazardous blood or body fluids, which have been documented in many previous studies among radiologists, pathologists, psychiatrists, dentists, and anesthesiologists[1-6].

Beginning in 1995, Taiwan launched the National Health Insurance (NHI) program and attempted to mitigate the health disparity among the general population living in different geographic regions. The provision of universal health care coverage has increased the health care demand[7-8]. For example, the number of outpatient visits per person increased from 10.56 in 1995 to 14.88 in 2008, and the numbers of hospitalized patients and outpatient visits per doctor increased as well[9-10]. , Thus, all the healthcare professionals, including doctors, have encountered a heavier workload and a greater psychosocial demand than before. However, a standardized mortality ratio (SMR) study using the general population as the reference for comparison did not detect any increased mortality among doctors in Taiwan[11].

From an alternative perspective, the association between demographic characteristics of human resources in health and the health of the population served has received considerable attention[12-13]. There is a growing evidence that the density of the health workforce is directly correlated with positive health outcomes in the population they serve, such as maternity mortality, infant mortality and life expectancy[14]. Other factors like geographic location, socioeconomic states and distribution of current health care resources might also affect health outcome and incline to inter-correlate with each other.

As all factors leading to health disparities are affecting people within respective locality[15], we hypothesized that they also influence the mortality rates of healthcare providers, including doctors who practiced in such locality. In the present study, we

used the cohort data from the registry of the doctor file maintained by the Taiwan Medical Association (TMA) and recruited internists, the largest group, as referents to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Methods

Subjects and data collection

The retrospective cohort was established from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. It contains the name of each individual, date and place of birth, gender, national identification number, medical school attended, date of graduation, self-designated specialty[11], place of practice, vital status, date of death for decedents, and date of ceasing the membership. The cohort was established beginning in January 1990 and followed up to December 2006. Practice time was accrued until 2006, or the date of deceased or termination of membership. There were 29 decedents with incomplete information on date or month of death, of which this study assumed to be on the first day of the month or year. Since all practicing doctors must be registered in compliance to the Doctors Act in Taiwan, the dataset is very comprehensive and accurate.

Statistical analysis

Geographic data in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth were collected and analyzed from national statistics of the Directorate General of Budget, Accounting and Statistics (Taiwan) in 1998, 2002, and 2006. Geographic region was categorized into northern, central, southern and eastern region following the naming of branches of Bureau of National Health Insurance. Education indicated the percentage of people aged more than 15 who attained an education level of college or above.

All-cause and cause-specific standardized mortality ratios (SMRs) were obtained by employing the personal computer version of Life Table Analysis System (LTAS.NET). The LTAS was originally developed by the National Institute for

Occupational Safety and Health (NIOSH) during the 1970s and was later converted for use on Windows 98/NT/2000/XP-compatible PCs. This program tabulates the underlying causes of death as well as the person-years of follow-up into age-, gender-, and race-specific strata, and allows users to apply internal controls as referents to replace general population from vital statistics. SMRs and 95% confidence intervals (CIs) were calculated using the mortality rates of 119 underlying causes of death of the internists of Taiwan as the reference group. We used SAS Version 9.1 (SAS institute) to edit and analyze the data. In this study, we set the significance level at p=0.05.

Cox regression analysis was conducted to determine the hazard ratios for the following risk factors: age, gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice (before or after 1995 when the NHI system was established), and doctor to population ratio. The ratio between doctors and population was categorized into 4 levels: larger than 1:500, from 1:500 to 1:700, from 1:700 to 1:900, and less than 1:900. Since the northern region of Taiwan leads development for the last half a century, it was chosen to be the reference in the statistical model. The covariates considered in the regression analysis were gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice, and doctor to population ratio. In Taiwan, some of our doctors were veteran who took ad-hoc medical missions during the world II and did not receive an academic medical education. They generally began their practices at an age older than most other doctors and deserved for this study to control as a potential confounder. We applied the stepwise strategy for variable selection with the significance level for entry and the significance level for stay set to 0.15. Regression diagnostics were also run, including examination of proportional hazard assumption, residual analysis, detection of influential cases, and check for multi-co-linearity to

assure the quality of analysis and goodness of fit for the model.

Results

With the doctor to population ratio above 1:500 as the reference level, we found that a lower ratio significantly increased the hazard ratio (HR) of doctor mortality; there was also an independent effect of regional difference of higher HR for southern and eastern regions, as summarized in Table 4. The differences among localities seemed to correlate well with higher average levels of income and education, lower infant mortality rates, and longer life expectancies across Taiwan. And such disparities did not appear to have changed during the last decade (Table 1).

A total of 37,545 doctors were tabulated in the study from January 1990 to December 2006. During the above period, there were 1642 deaths among 32,713 male doctors and 44 deaths among 4822 female doctors. The overall mean age at death was 69.88± 14.28 years old, with 70.06±14.04 for males and 62.96±20.21 for females, respectively. (Table 2) Approximately half (49.7%) of the cohort had been internists, 48.1% were practicing in the north region. Among all doctors, there were 30.8% working in the area of low doctor to population ratio. About two-thirds began their practice before 1995, and over 90% started practice at age below 40.

As for the control for socioeconomic status in the analysis, we used the internists as the reference population and found that the all cause specific SMRs for surgeons and anesthesiologists were marginally elevated with an SMR of 1.15 (95% CI: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64), respectively (Table 3). Among the surgeons, the SMR of “Neoplasm of lymphatic and hematopoietic tissue” was increased but without statistical significance (SMR = 2.17, 95% CI: 0.94 to 4.28). The observed numbers of deaths from malignant neoplasm of digestive organs and peritoneum were significantly lower than corresponding expected values (SMR =0.54, $p < 0.05$, 95% CI: 0.29 to 0.92). Among the anesthesiologists, the SMR of “malignant neoplasm of other and unspecified sites” was significantly increased (SMR =8.73, $p < 0.05$, 95%

CI: 1.06 to 31.53), although there were only 2 cases on the observed number.

To further adjust for other risk factors, the Cox regression model was constructed and the results were summarized in Table 4. The anesthesiologists appeared to show the highest hazard ratios (HRs) of 1.97 (95% CI, 1.20 to 3.25), followed by surgeons with a HR of 1.23 (95%CI, 1.04 to 1.46). The HR of ophthalmologists was significantly lower than all other specialists, of which the HR was 0.72 (95%CI, 0.53 to 0.98). In addition, doctors living in the northern region and the central region experienced lower HR's. And doctors who worked in the area with doctor to population ratio below 1:500 showed higher mortality or HR.

The doctors who began practice at an older age had a higher HR of 1.12 (95%CI, 1.12 to 1.13) for every single year increment. Overall, doctors who began practice after the implementation of NHI Program, or the year of 1995, showed a higher HR of 6.17 (95%CI, 4.27 to 8.92).

Discussion

Based on Cox's Model analysis, we found doctors practicing in southern and eastern regions of Taiwan suffered from statistically significant premature mortality (Table 4), and such a geographic disparity appeared to correspond to the lower life expectancy and higher infant mortality rate in Taiwan (Table 1). To our limited knowledge, this study is the first to show that doctors practicing in the area of a low doctor to population ratio or in the less resourceful regions experienced a higher HR of mortality after adjustment for gender, age of beginning practice, and specialties (Table 4). Because doctors in Taiwan generally have higher earnings than all other segments of professionals and there is no upper limit of retirement age, we have decided to select "internal comparisons" among doctors with the same socioeconomic status, profession-related knowledge and health-related behaviour, to prevent confounding and would leave the effects of mortality to the other two main factors, occupational workload or practice environment.

Lowest average income, educational level and life expectancy, and the highest infant mortality rate in Taiwan were found in the eastern region (Table 1). Traditionally, this mountainous region impedes transportation tremendously, and plays a significant role in reduced healthcare accessibility for people, including health care providers themselves. Although the doctor to population ratio has improved since the promulgation of Medical Care Act in 1986 and implementation of NHI in 1995, doctors living in this region still suffer from a higher HR. It may indicate that the health disparity still exists. Moreover, in analyzing the central and southern regions, where similar levels of the average income and the education were found, a significantly increased hazard ratio was detected in the southern region only. As noted in Table 1, the doctor to population ratio has been consistently found to be lower in the southern region compared with those of the northern and central regions. These findings indicate persistent health disparities in different regions of Taiwan, and suggest that occupational workloads might play some role in view of the increased mortality of doctors.

In a previous study, we found that the overall and cause-specific SMRs of doctors in Taiwan were less than 0.34 for different specialties[11], which may have been confounded by using the general population as the referents for comparison[16]. In this study, we use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states (Table 3). Although no increased mortality was found among radiologists, pathologists, and psychiatrists, as reported from other countries[2-4], we detected significantly increased HRs for surgeons and anesthesiologists (Table 4). A further analysis only detected slightly elevated SMR for malignant neoplasm of lymphatic and hematopoietic tissues among surgeons, which appeared to corroborate the hazards of operation room reported by others[17]. However, the trend was less apparent because of the small sample size of anesthesiologists. Since the current mortality data in Taiwan only allowed for coding single underlying cause of death, it may further decrease the power of detection of occupational related illnesses.

Our study also demonstrated the HR of mortality was higher in the group beginning their practice since 1995, when the National Health Insurance system was implemented. This group belonged to a younger generation of doctors, who might possibly suffer from highly stressed work during their practice[18]. Such a stress might arise from their clinical training program or the newly implemented health policy. However, the cohort was established during 1990-2006, which may have imposed a selection of healthy survivors among the doctors. They began their practice before 1995 in comparison with those who entered the workforce after 1995. Thus, more study is needed to explore the above hypothesis.

Several limitations of this study should be noted. Firstly, possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties. For instance, a surgeon shifted to general practice after retiring from a medical center may result in overestimation of the practice duration and possible underestimation of the effect of specialty. Thus, the higher HR's among surgeons and anesthesiologists may need to be further studied for clarification. Secondly, information was limited about the hospital level and the locations which the doctor has practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

In conclusion, disparities both in the geographic region of doctor's practice and the ratio of doctor to population regionally are the primary determinants to the HR of doctor mortality. Thus, we recommend increasing the number of doctors and improving the practice environment of eastern and southern regions of Taiwan, which may possibly mitigate the health disparities among doctors and people. Further, more studies are needed to explore and reduce the potential hazards among workplaces of anesthesiologists and surgeons in Taiwan.

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Contribution statement

The first author, Dr. Tung-Fu Shang, has acquired the dataset, designed the study together with Dr. Wang (the corresponding author), conducted the analysis under the full supervision and discussion with Drs. Chen and Wang, written the first draft, and all three participated in the revision of the later drafts until the final one.

Dr. Shang has access to all the data in the study and takes responsibility for the integrity of the data. Together with all co-authors, we shall be responsible for the accuracy of the data analysis, interpretation of the results.

Competing interests:

All authors of this manuscript indicate no conflicts of interest and have complied with the Principles of Ethical Practice of Public Health. The Ethics Review Board of our institute (Institute of Occupational Medicine and Industrial Hygiene College of Public Health, National Taiwan University, Taiwan) approved the protocol before the commencement of this study.

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Table 1 -- Geographic disparities in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth in 1998, 2002, and 2006.

Region	Doctors per 10,000 persons			Per capita disposable income			Education §			Infant mortality rate			Life expectancy		
	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006
Northern	14.7	16.5	17.4	8394.8	8912.6	9853.0	24.8	30.1	36.1	6.2	4.9	4.4	77.4	78.6	79.5
Central	14.1	16.5	18.3	7044.2	6940.0	7817.6	18.8	23.2	28.6	6.9	5.8	4.5	75.1	77.0	77.6
Southern	12.9	14.5	16.5	6928.8	7157.5	7891.2	18.4	22.8	27.7	6.4	5.4	4.8	74.7	76.0	76.5
Eastern	13.3	15.4	18.3	6542.2	6683.0	7987.6	11.8	14.4	20.0	12.4	8.3	7.6	70.6	72.9	73.2

§**Education**: The percentage of people aged more than 15 attained an education level of college or above

Table 2 -- Characteristics of Taiwan doctors included in the study from 1990 to 2006.

	Taiwan doctors		Deceased doctors	
	No. (%)	mean censored age	No. (%)	mean age at death
Total	37,545 (100)	46.41±14.47	1686 (100)	69.88±14.28
Status				
Alive	35,859 (95.5)	45.31±13.51		
Deceased	1686 (4.5)			69.88±14.28
Sex				
Male	32,722 (87.2)	47.68±14.56	1642 (97.4)	70.06±14.04
Female	4823 (12.8)	37.81±10.30	44 (2.6)	62.96±20.21
Age of beginning practice				
age<30	29,753 (79.2)	43.39±11.99	566 (33.6)	59.03±14.98
30<=age<40	5573 (14.8)	52.28±14.10	472 (28.0)	73.81±11.92
age≧40	2219 (5.9)	74.24±10.91	648 (38.4)	76.37±8.62
Specialty				
Surgeon	4571 (12.2)	45.20±13.20	161 (9.5)	65.83±14.54
Internist	18,664 (49.7)	48.76±15.97	1190 (70.1)	71.92±12.70
Dermatologist	901 (2.4)	43.00±12.92	35 (2.1)	69.79±16.25
Otolaryngologist	2000 (5.3)	44.28±11.99	45 (2.7)	65.46±14.36
Ophthalmologist	1584 (4.2)	44.72±12.33	42 (2.5)	72.28±19.56
Pathologist	414 (1.1)	42.21±12.04	5 (0.3)	49.78±10.87
Pediatrician	2883 (7.7)	42.35±11.59	54 (3.2)	66.32±17.12

Psychiatrist	1214 (3.2)	40.37±11.81	21 (1.2)	61.85±20.52
Radiologist	1076 (2.9)	41.59±11.79	18 (1.1)	63.23±18.18
Obstetrician	2278 (6.1)	48.84±12.10	85 (5.0)	63.48±14.44
Orthopedist	1128 (3.0)	43.56±11.07	14 (0.8)	58.78±18.32
Anesthesiologist	832 (2.2)	40.91±10.23	16 (0.9)	45.21±15.67
Region				
Northern	18,046 (48.1)	45.71±14.52	659 (39.1)	68.90±14.32
Central	7054 (18.8)	46.25±13.70	300 (17.8)	70.04±15.58
Southern	11,376 (30.3)	47.64±14.81	667 (39.6)	70.97±13.57
Eastern	1069 (2.8)	46.24±14.12	60 (3.6)	67.67±13.96
Doctor-population ratio				
＞1：500	17,185 (45.8)	45.29±14.34	620 (36.8)	68.21±15.11
1：700 to 1：500	6429 (17.1)	45.55±14.50	285 (16.9)	69.71±14.19
1：900 to 1：700	11,233 (29.9)	47.91±14.21	589 (34.9)	70.92±13.61
＜1：900	2698 (7.2)	51.08±14.53	192 (11.4)	71.90±13.02
Years of practice				
Before 1995	24,337 (64.8)	53.62±12.71	1640 (97.3)	70.60±13.52
After 1995	13,208 (35.2)	33.13±5.06	46 (2.7)	44.28±16.86

Table 3 -- The observed number of deaths and cause specific SMRs (standardized mortality ratios) for surgeons and anesthesiologists, using internists of Taiwan as the reference group.

	Surgeon			Anesthesiologist		
Causes of death	**O**	**SMR**	**95%CI** §	**O**	**SMR**	**95%CI**
All causes	161	1.15	(0.98 - 1.34)	16	1.62	(0.93 - 2.64)
All malignant neoplasm (MN)	37	0.84	(0.59 - 1.16)	5	1.57	(0.51 - 3.66)
MN of digestive organs and peritoneum	13	0.54	(0.29 -0.92)	2	1.18	(0.14 -4.26)
MN of respiratory system	11	1.16	(0.58 - 2.07)	0	0.00	(0.00- 6.56)
MN of urinary organs	2	1.05	(0.13 - 3.79)	0	0.00	(0.00 - 20.42)
Neoplasm of lymphatic and hematopoietic tissue	8	2.17	(0.94 - 4.28)	1	3.41	(0.09 -19.03)
MN of other and unspecified sites	1	0.48	(0.01 -2.68)	2	8.73	(1.06 - 31.53)
Cerebrovascular disease	7	0.59	(0.24 - 1.22)	3	3.95	(0.82 - 11.55)
Heart disease	9	0.83	(0.38 -1.57)	0	0.00	(0.00 - 7.34)
Accidents	11	1.81	(0.90 -3.24)	1	1.58	(0.04 - 8.79)
Diabetes mellitus	8	1.49	(0.65 -2.94)	1	1.84	(0.05 -10.25)
Chronic liver disease	7	1.60	(0.64 -3.30)	0	0.00	(0.00 -13.75)
Kidney disease	1	0.36	(0.01 -2.01)	0	0.00	(0.00 -21.26)
Pneumonia	5	0.97	(0.32 - 2.27)	0	0.00	(0.00 -12.23)
Suicide	3	1.36	(0.28 - 3.98)	1	3.34	(0.08 -18.60)

Chronic lung disease	4	2.19	(0.60 - 5.60)	0	0.00	(0.00 -116.04)
Hypertensive disease	2	1.45	(0.18 - 5.25)	0	0.00	(0.00 - 30.76)

§ **CI: confidence interval**

Table 4 -- Hazard ratios with 95% CI (confidence interval) estimated through Cox regression model to control relevant risk factors on mortality among Taiwan doctors from 1990 to 2006.

Covariate	Hazard ratio	95% CI
Age of beginning practice		
	1.12	1.12-1.13
Gender		
Female/male	0.76	0.56-1.02
Specialty		
Dermatologist / Internist	1.19	0.85-1.67
Otolaryngologist / Internist	0.85	0.63-1.15
Ophthalmologist / Internist	0.72	0.53-0.98
Pathologist/ Internist	0.81	0.33-1.94
Pediatrician / Internist	0.91	0.69-1.20
Psychiatrist / Internist	0.81	0.52-1.24
Radiologist / Internist	0.87	0.55-1.39
Surgeon / Internist	1.23	1.04-1.46
Obstetrician / Internist	1.19	0.95-1.50
Orthopedist / Internist	0.75	0.44-1.27
Anesthesiologists/ Internist	1.97	1.20-3.25
Region		
Central / Northern	1.12	0.97-1.29
Southern / Northern	1.30	1.17-1.45
Eastern / Northern	1.68	1.28-2.20
Doctor-population ratio		

1：700 to 1：500 / ＞1：500	1.23	1.06-1.42
1：900 to 1：700 / ＞1：500	1.20	1.06-1.34
＜1：900 / ＞1：500	1.18	1.00-1.39
Year of beginning practice		
After 1995/ Before1995	6.17	4.27-8.92

WHAT IS ALREADY KNOWN ON THIS TOPIC

All factors leading to health disparities are affecting people within respective locality.

WHAT THIS STUDY ADDS

All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.

Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Disparities in Mortality among Doctors in Taiwan:

A 17-year follow-up study of 37,545 Doctors

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Objectives. We used cohort data from the registry of all doctors in Taiwan to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Design. Retrospective cohort study, 1990-2006.

Settings. The Taiwan Medical Association (TMA).

Participants. A total of 37,545 doctors from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors.

Main outcome measures. Cause-specific standardized mortality ratios (SMRs) for surgeons and anesthesiologists were compared to those of the internists. Cox's proportional hazard model was constructed to explore multiple risk factors for mortality, including specialties, age, gender, geographic region of practices, regional health resources, ages of beginning practices, and years of beginning practice.

Results. The all-cause specific SMRs for surgeons and anesthesiologists were marginally elevated at 1.15 (95% confidence interval: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64) respectively. The Cox regression model showed that the anesthesiologists had the highest hazard ratio (HR) of 1.97, seconded by surgeons at 1.23. Localities with the doctor to population ratio lower than 1:500 were associated with an increased HR of doctor mortality.

Conclusions. The doctor to population ratio and the region of practice may influence doctor's mortality. Increasing number of doctors and/or improving the practice environment may be helpful in reducing the health disparities in regions with poor resources.

Article Summary

Article focus

To determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Key messages

- All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.
- Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Strengths and limitations of this study

Strengths

- The cohort data includes all practicing doctors in Taiwan.
- We use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states.

Limitations

- Possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties.
- Information was limited about the hospital level and location practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting.

During practices, health care providers have already been noted to suffer from certain specific potential hazards like stress, radiation, anesthetic gases or agents and biologically hazardous blood or body fluids, which have been documented in many previous studies among radiologists, pathologists, psychiatrists, dentists, and anesthesiologists[1-6].

Beginning in 1995, Taiwan launched the National Health Insurance (NHI) program and attempted to mitigate the health disparity among the general population living in different geographic regions. The provision of universal health care coverage has increased the health care demand[7-8]. For example, the number of outpatient visits per person increased from 10.56 in 1995 to 14.88 in 2008, and the numbers of hospitalized patients and outpatient visits per doctor increased as well[9-10]. , Thus, all the healthcare professionals, including doctors, have encountered a heavier workload and a greater psychosocial demand than before. However, a standardized mortality ratio (SMR) study using the general population as the reference for comparison did not detect any increased mortality among doctors in Taiwan[11].

From an alternative perspective, the association between demographic characteristics of human resources in health and the health of the population served has received considerable attention[12-13]. There is a growing evidence that the density of the health workforce is directly correlated with positive health outcomes in the population they serve, such as maternity mortality, infant mortality and life expectancy[14]. Other factors like geographic location, socioeconomic states and distribution of current health care resources might also affect health outcome and incline to inter-correlate with each other.

As all factors leading to health disparities are affecting people within respective locality[15], we hypothesized that they also influence the mortality rates of healthcare providers, including doctors who practiced in such locality. In the present study, we

used the cohort data from the registry of the doctor file maintained by the Taiwan Medical Association (TMA) and recruited internists, the largest group, as referents to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Methods

Subjects and data collection

The retrospective cohort was established from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. It contains the name of each individual, date and place of birth, gender, national identification number, medical school attended, date of graduation, self-designated specialty[11], place of practice, vital status, date of death for decedents, and date of ceasing the membership. The cohort was established beginning in January 1990 and followed up to December 2006. Practice time was accrued until 2006, or the date of deceased or termination of membership. There were 29 decedents with incomplete information on date or month of death, of which this study assumed to be on the first day of the month or year. Since all practicing doctors must be registered in compliance to the Doctors Act in Taiwan, the dataset is very comprehensive and accurate.

Statistical analysis

Geographic data in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth were collected and analyzed from national statistics of the Directorate General of Budget, Accounting and Statistics (Taiwan) in 1998, 2002, and 2006. Geographic region was categorized into northern, central, southern and eastern region following the naming of branches of Bureau of National Health Insurance. Education indicated the percentage of people aged more than 15 who attained an education level of college or above.

All-cause and cause-specific standardized mortality ratios (SMRs) were obtained by employing the personal computer version of Life Table Analysis System (LTAS.NET). The LTAS was originally developed by the National Institute for

Occupational Safety and Health (NIOSH) during the 1970s and was later converted for use on Windows 98/NT/2000/XP-compatible PCs. This program tabulates the underlying causes of death as well as the person-years of follow-up into age-, gender-, and race-specific strata, and allows users to apply internal controls as referents to replace general population from vital statistics. SMRs and 95% confidence intervals (CIs) were calculated using the mortality rates of 119 underlying causes of death of the internists of Taiwan as the reference group. We used SAS Version 9.1 (SAS institute) to edit and analyze the data. In this study, we set the significance level at p=0.05.

Cox regression analysis was conducted to determine the hazard ratios for the following risk factors: age, gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice (before or after 1995 when the NHI system was established), and doctor to population ratio. The ratio between doctors and population was categorized into 4 levels: larger than 1:500, from 1:500 to 1:700, from 1:700 to 1:900, and less than 1:900. Since the northern region of Taiwan leads development for the last half a century, it was chosen to be the reference in the statistical model. The covariates considered in the regression analysis were gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice, and doctor to population ratio. In Taiwan, some of our doctors were veteran who took ad-hoc medical missions during the world II and did not receive an academic medical education. They generally began their practices at an age older than most other doctors and deserved for this study to control as a potential confounder. We applied the stepwise strategy for variable selection with the significance level for entry and the significance level for stay set to 0.15. Regression diagnostics were also run, including examination of proportional hazard assumption, residual analysis, detection of influential cases, and check for multi-co-linearity to

assure the quality of analysis and goodness of fit for the model.

Results

With the doctor to population ratio above 1:500 as the reference level, we found that a lower ratio significantly increased the hazard ratio (HR) of doctor mortality; there was also an independent effect of regional difference of higher HR for southern and eastern regions, as summarized in Table 4. The differences among localities seemed to correlate well with higher average levels of income and education, lower infant mortality rates, and longer life expectancies across Taiwan. And such disparities did not appear to have changed during the last decade (Table 1).

A total of 37,545 doctors were tabulated in the study from January 1990 to December 2006. During the above period, there were 1642 deaths among 32,713 male doctors and 44 deaths among 4822 female doctors. The overall mean age at death was 69.88± 14.28 years old, with 70.06±14.04 for males and 62.96±20.21 for females, respectively. (Table 2) Approximately half (49.7%) of the cohort had been internists, 48.1% were practicing in the north region. Among all doctors, there were 30.8% working in the area of low doctor to population ratio. About two-thirds began their practice before 1995, and over 90% started practice at age below 40.

As for the control for socioeconomic status in the analysis, we used the internists as the reference population and found that the all cause specific SMRs for surgeons and anesthesiologists were marginally elevated with an SMR of 1.15 (95% CI: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64), respectively (Table 3). Among the surgeons, the SMR of "Neoplasm of lymphatic and hematopoietic tissue" was increased but without statistical significance (SMR = 2.17, 95% CI: 0.94 to 4.28). The observed numbers of deaths from malignant neoplasm of digestive organs and peritoneum were significantly lower than corresponding expected values (SMR =0.54, $p < 0.05$, 95% CI: 0.29 to 0.92). Among the anesthesiologists, the SMR of "malignant neoplasm of other and unspecified sites" was significantly increased (SMR =8.73, $p < 0.05$, 95%

CI: 1.06 to 31.53), although there were only 2 cases on the observed number.

To further adjust for other risk factors, the Cox regression model was constructed and the results were summarized in Table 4. The anesthesiologists appeared to show the highest hazard ratios (HRs) of 1.97 (95% CI, 1.20 to 3.25), followed by surgeons with a HR of 1.23 (95%CI, 1.04 to 1.46). The HR of ophthalmologists was significantly lower than all other specialists, of which the HR was 0.72 (95%CI, 0.53 to 0.98). In addition, doctors living in the northern region and the central region experienced lower HR's. And doctors who worked in the area with doctor to population ratio below 1:500 showed higher mortality or HR.

The doctors who began practice at an older age had a higher HR of 1.12 (95%CI, 1.12 to 1.13) for every single year increment. Overall, doctors who began practice after the implementation of NHI Program, or the year of 1995, showed a higher HR of 6.17 (95%CI, 4.27 to 8.92).

Discussion

Based on Cox's Model analysis, we found doctors practicing in southern and eastern regions of Taiwan suffered from statistically significant premature mortality (Table 4), and such a geographic disparity appeared to correspond to the lower life expectancy and higher infant mortality rate in Taiwan (Table 1). To our limited knowledge, this study is the first to show that doctors practicing in the area of a low doctor to population ratio or in the less resourceful regions experienced a higher HR of mortality after adjustment for gender, age of beginning practice, and specialties (Table 4). Because doctors in Taiwan generally have higher earnings than all other segments of professionals and there is no upper limit of retirement age, we have decided to select "internal comparisons" among doctors with the same socioeconomic status, profession-related knowledge and health-related behaviour, to prevent confounding and would leave the effects of mortality to the other two main factors, occupational workload or practice environment.

Lowest average income, educational level and life expectancy, and the highest infant mortality rate in Taiwan were found in the eastern region (Table 1). Traditionally, this mountainous region impedes transportation tremendously, and plays a significant role in reduced healthcare accessibility for people, including health care providers themselves. Although the doctor to population ratio has improved since the promulgation of Medical Care Act in 1986 and implementation of NHI in 1995, doctors living in this region still suffer from a higher HR. It may indicate that the health disparity still exists. Moreover, in analyzing the central and southern regions, where similar levels of the average income and the education were found, a significantly increased hazard ratio was detected in the southern region only. As noted in Table 1, the doctor to population ratio has been consistently found to be lower in the southern region compared with those of the northern and central regions. These findings indicate persistent health disparities in different regions of Taiwan, and suggest that occupational workloads might play some role in view of the increased mortality of doctors.

In a previous study, we found that the overall and cause-specific SMRs of doctors in Taiwan were less than 0.34 for different specialties[11], which may have been confounded by using the general population as the referents for comparison[16]. In this study, we use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states (Table 3). Although no increased mortality was found among radiologists, pathologists, and psychiatrists, as reported from other countries[2-4], we detected significantly increased HRs for surgeons and anesthesiologists (Table 4). A further analysis only detected slightly elevated SMR for malignant neoplasm of lymphatic and hematopoietic tissues among surgeons, which appeared to corroborate the hazards of operation room reported by others[17]. However, the trend was less apparent because of the small sample size of anesthesiologists. Since the current mortality data in Taiwan only allowed for coding single underlying cause of death, it may further decrease the power of detection of occupational related illnesses.

Our study also demonstrated the HR of mortality was higher in the group beginning their practice since 1995, when the National Health Insurance system was implemented. This group belonged to a younger generation of doctors, who might possibly suffer from highly stressed work during their practice[18]. Such a stress might arise from their clinical training program or the newly implemented health policy. However, the cohort was established during 1990-2006, which may have imposed a selection of healthy survivors among the doctors. They began their practice before 1995 in comparison with those who entered the workforce after 1995. Thus, more study is needed to explore the above hypothesis.

Several limitations of this study should be noted. Firstly, possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties. For instance, a surgeon shifted to general practice after retiring from a medical center may result in overestimation of the practice duration and possible underestimation of the effect of specialty. Thus, the higher HR's among surgeons and anesthesiologists may need to be further studied for clarification. Secondly, information was limited about the hospital level and the locations which the doctor has practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

In conclusion, disparities both in the geographic region of doctor's practice and the ratio of doctor to population regionally are the primary determinants to the HR of doctor mortality. Thus, we recommend increasing the number of doctors and improving the practice environment of eastern and southern regions of Taiwan, which may possibly mitigate the health disparities among doctors and people. Further, more studies are needed to explore and reduce the potential hazards among workplaces of anesthesiologists and surgeons in Taiwan.

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Contribution statement

The first author, Dr. Tung-Fu Shang, has acquired the dataset, designed the study together with Dr. Wang (the corresponding author), conducted the analysis under the full supervision and discussion with Drs. Chen and Wang, written the first draft, and all three participated in the revision of the later drafts until the final one.

Dr. Shang has access to all the data in the study and takes responsibility for the integrity of the data. Together with all co-authors, we shall be responsible for the accuracy of the data analysis, interpretation of the results.

Competing interests:

All authors of this manuscript indicate no conflicts of interest and have complied with the Principles of Ethical Practice of Public Health. The Ethics Review Board of our institute (Institute of Occupational Medicine and Industrial Hygiene College of Public Health, National Taiwan University, Taiwan) approved the protocol before the commencement of this study.

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Table 1 -- Geographic disparities in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth in 1998, 2002, and 2006.

Region	Doctors per 10,000 persons			Per capita disposable income			Education [§]			Infant mortality rate			Life expectancy		
	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006
Northern	14.7	16.5	17.4	8394.8	8912.6	9853.0	24.8	30.1	36.1	6.2	4.9	4.4	77.4	78.6	79.5
Central	14.1	16.5	18.3	7044.2	6940.0	7817.6	18.8	23.2	28.6	6.9	5.8	4.5	75.1	77.0	77.6
Southern	12.9	14.5	16.5	6928.8	7157.5	7891.2	18.4	22.8	27.7	6.4	5.4	4.8	74.7	76.0	76.5
Eastern	13.3	15.4	18.3	6542.2	6683.0	7987.6	11.8	14.4	20.0	12.4	8.3	7.6	70.6	72.9	73.2

[§]**Education**: The percentage of people aged more than 15 attained an education level of college or above

Table 2 -- Characteristics of Taiwan doctors included in the study from 1990 to 2006.

	Taiwan doctors		Deceased doctors	
	No. (%)	mean censored age	No. (%)	mean age at death
Total	37,545 (100)	46.41±14.47	1686 (100)	69.88±14.28
Status				
Alive	35,859 (95.5)	45.31±13.51		
Deceased	1686 (4.5)			69.88±14.28
Sex				
Male	32,722 (87.2)	47.68±14.56	1642 (97.4)	70.06±14.04
Female	4823 (12.8)	37.81±10.30	44 (2.6)	62.96±20.21
Age of beginning practice				
age<30	29,753 (79.2)	43.39±11.99	566 (33.6)	59.03±14.98
30<=age<40	5573 (14.8)	52.28±14.10	472 (28.0)	73.81±11.92
age≧40	2219 (5.9)	74.24±10.91	648 (38.4)	76.37±8.62
Specialty				
Surgeon	4571 (12.2)	45.20±13.20	161 (9.5)	65.83±14.54
Internist	18,664 (49.7)	48.76±15.97	1190 (70.1)	71.92±12.70
Dermatologist	901 (2.4)	43.00±12.92	35 (2.1)	69.79±16.25
Otolaryngologist	2000 (5.3)	44.28±11.99	45 (2.7)	65.46±14.36
Ophthalmologist	1584 (4.2)	44.72±12.33	42 (2.5)	72.28±19.56
Pathologist	414 (1.1)	42.21±12.04	5 (0.3)	49.78±10.87
Pediatrician	2883 (7.7)	42.35±11.59	54 (3.2)	66.32±17.12

Psychiatrist	1214 (3.2)	40.37±11.81	21 (1.2)	61.85±20.52
Radiologist	1076 (2.9)	41.59±11.79	18 (1.1)	63.23±18.18
Obstetrician	2278 (6.1)	48.84±12.10	85 (5.0)	63.48±14.44
Orthopedist	1128 (3.0)	43.56±11.07	14 (0.8)	58.78±18.32
Anesthesiologist	832 (2.2)	40.91±10.23	16 (0.9)	45.21±15.67
Region				
Northern	18,046 (48.1)	45.71±14.52	659 (39.1)	68.90±14.32
Central	7054 (18.8)	46.25±13.70	300 (17.8)	70.04±15.58
Southern	11,376 (30.3)	47.64±14.81	667 (39.6)	70.97±13.57
Eastern	1069 (2.8)	46.24±14.12	60 (3.6)	67.67±13.96
Doctor-population ratio				
＞1：500	17,185 (45.8)	45.29±14.34	620 (36.8)	68.21±15.11
1：700 to 1：500	6429 (17.1)	45.55±14.50	285 (16.9)	69.71±14.19
1：900 to 1：700	11,233 (29.9)	47.91±14.21	589 (34.9)	70.92±13.61
＜1：900	2698 (7.2)	51.08±14.53	192 (11.4)	71.90±13.02
Years of practice				
Before 1995	24,337 (64.8)	53.62±12.71	1640 (97.3)	70.60±13.52
After 1995	13,208 (35.2)	33.13±5.06	46 (2.7)	44.28±16.86

Table 3 -- The observed number of deaths and cause specific SMRs (standardized mortality ratios) for surgeons and anesthesiologists, using internists of Taiwan as the reference group.

	Surgeon			Anesthesiologist		
Causes of death	**O**	**SMR**	**95%CI §**	**O**	**SMR**	**95%CI**
All causes	161	1.15	(0.98 - 1.34)	16	1.62	(0.93 - 2.64)
All malignant neoplasm (MN)	37	0.84	(0.59 - 1.16)	5	1.57	(0.51 - 3.66)
MN of digestive organs and peritoneum	13	0.54	(0.29 -0.92)	2	1.18	(0.14 -4.26)
MN of respiratory system	11	1.16	(0.58 - 2.07)	0	0.00	(0.00- 6.56)
MN of urinary organs	2	1.05	(0.13 - 3.79)	0	0.00	(0.00 - 20.42)
Neoplasm of lymphatic and hematopoietic tissue	8	2.17	(0.94 - 4.28)	1	3.41	(0.09 -19.03)
MN of other and unspecified sites	1	0.48	(0.01 -2.68)	2	8.73	(1.06 - 31.53)
Cerebrovascular disease	7	0.59	(0.24 - 1.22)	3	3.95	(0.82 - 11.55)
Heart disease	9	0.83	(0.38 -1.57)	0	0.00	(0.00 - 7.34)
Accidents	11	1.81	(0.90 -3.24)	1	1.58	(0.04 - 8.79)
Diabetes mellitus	8	1.49	(0.65 -2.94)	1	1.84	(0.05 -10.25)
Chronic liver disease	7	1.60	(0.64 -3.30)	0	0.00	(0.00 -13.75)
Kidney disease	1	0.36	(0.01 -2.01)	0	0.00	(0.00 -21.26)
Pneumonia	5	0.97	(0.32 - 2.27)	0	0.00	(0.00 -12.23)
Suicide	3	1.36	(0.28 - 3.98)	1	3.34	(0.08 -18.60)

Chronic lung disease	4	2.19	(0.60 - 5.60)	0	0.00	(0.00 -116.04)
Hypertensive disease	2	1.45	(0.18 - 5.25)	0	0.00	(0.00 - 30.76)

[§] **CI: confidence interval**

Table 4 -- Hazard ratios with 95% CI (confidence interval) estimated through Cox regression model to control relevant risk factors on mortality among Taiwan doctors from 1990 to 2006.

Covariate	Hazard ratio	95% CI
Age of beginning practice		
	1.12	1.12-1.13
Gender		
Female/male	0.76	0.56-1.02
Specialty		
Dermatologist / Internist	1.19	0.85-1.67
Otolaryngologist / Internist	0.85	0.63-1.15
Ophthalmologist / Internist	0.72	0.53-0.98
Pathologist/ Internist	0.81	0.33-1.94
Pediatrician / Internist	0.91	0.69-1.20
Psychiatrist / Internist	0.81	0.52-1.24
Radiologist / Internist	0.87	0.55-1.39
Surgeon / Internist	1.23	1.04-1.46
Obstetrician / Internist	1.19	0.95-1.50
Orthopedist / Internist	0.75	0.44-1.27
Anesthesiologists/ Internist	1.97	1.20-3.25
Region		
Central / Northern	1.12	0.97-1.29
Southern / Northern	1.30	1.17-1.45
Eastern / Northern	1.68	1.28-2.20
Doctor-population ratio		

1：700 to 1：500 / ＞1：500	1.23	1.06-1.42
1：900 to 1：700 / ＞1：500	1.20	1.06-1.34
＜1：900 / ＞1：500	1.18	1.00-1.39
Year of beginning practice		
After 1995/ Before1995	6.17	4.27-8.92

WHAT IS ALREADY KNOWN ON THIS TOPIC

All factors leading to health disparities are affecting people within respective locality.

WHAT THIS STUDY ADDS

All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.

Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			**4-5**
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			**6-7**
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			8-9

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9
		(*b*) Report category boundaries when continuous variables were categorized	8-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-9
Discussion			10-11
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-12
Other information			13
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Disparities in Mortality among Doctors in Taiwan: A 17-year follow-up study of 37,545 Doctors

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Disparities in Mortality among Doctors in Taiwan:

A 17-year follow-up study of 37,545 Doctors

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Objectives. We used cohort data from the registry of all doctors in Taiwan to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Design. Retrospective cohort study, 1990-2006.

Settings. The Taiwan Medical Association (TMA).

Participants. A total of 37,545 doctors from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors.

Main outcome measures. Cause-specific standardized mortality ratios (SMRs) for surgeons and anesthesiologists were compared to those of the internists. Cox's proportional hazard model was constructed to explore multiple risk factors for mortality, including specialties, age, gender, geographic region of practices, regional health resources, ages of beginning practices, and years of beginning practice.

Results. The all-cause specific SMRs for surgeons and anesthesiologists were marginally elevated at 1.15 (95% confidence interval: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64) respectively. The Cox regression model showed that the anesthesiologists had the highest hazard ratio (HR) of 1.97, seconded by surgeons at 1.23. Localities with the doctor to population ratio lower than 1:500 were associated with an increased HR of doctor mortality.

Conclusions. The doctor to population ratio and the region of practice may influence doctor's mortality. Increasing number of doctors and/or improving the practice environment may be helpful in reducing the health disparities in regions with poor resources.

Article Summary

Article focus

To determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Key messages

- All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.
- Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Strengths and limitations of this study

Strengths

- The cohort data includes all practicing doctors in Taiwan.
- We use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states.

Limitations

- Possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties.
- Information was limited about the hospital level and location practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting.

During practices, health care providers have already been noted to suffer from certain specific potential hazards like stress, radiation, anesthetic gases or agents and biologically hazardous blood or body fluids, which have been documented in many previous studies among radiologists, pathologists, psychiatrists, dentists, and anesthesiologists[1-6].

Beginning in 1995, Taiwan launched the National Health Insurance (NHI) program and attempted to mitigate the health disparity among the general population living in different geographic regions. The provision of universal health care coverage has increased the health care demand[7-8]. For example, the number of outpatient visits per person increased from 10.56 in 1995 to 14.88 in 2008, and the numbers of hospitalized patients and outpatient visits per doctor increased as well[9-10]. , Thus, all the healthcare professionals, including doctors, have encountered a heavier workload and a greater psychosocial demand than before. However, a standardized mortality ratio (SMR) study using the general population as the reference for comparison did not detect any increased mortality among doctors in Taiwan[11].

From an alternative perspective, the association between demographic characteristics of human resources in health and the health of the population served has received considerable attention[12-13]. There is a growing evidence that the density of the health workforce is directly correlated with positive health outcomes in the population they serve, such as maternity mortality, infant mortality and life expectancy[14]. Other factors like geographic location, socioeconomic states and distribution of current health care resources might also affect health outcome and incline to inter-correlate with each other.

As all factors leading to health disparities are affecting people within respective locality[15], we hypothesized that they also influence the mortality rates of healthcare providers, including doctors who practiced in such locality. In the present study, we

used the cohort data from the registry of the doctor file maintained by the Taiwan Medical Association (TMA) and recruited internists, the largest group, as referents to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Methods

Subjects and data collection

The retrospective cohort was established from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. It contains the name of each individual, date and place of birth, gender, national identification number, medical school attended, date of graduation, self-designated specialty[11], place of practice, vital status, date of death for decedents, and date of ceasing the membership. The cohort was established beginning in January 1990 and followed up to December 2006. Practice time was accrued until 2006, or the date of deceased or termination of membership. There were 29 decedents with incomplete information on date or month of death, of which this study assumed to be on the first day of the month or year. Since all practicing doctors must be registered in compliance to the Doctors Act in Taiwan, the dataset is very comprehensive and accurate.

Statistical analysis

Geographic data in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth were collected and analyzed from national statistics of the Directorate General of Budget, Accounting and Statistics (Taiwan) in 1998, 2002, and 2006. Geographic region was categorized into northern, central, southern and eastern region following the naming of branches of Bureau of National Health Insurance. Education indicated the percentage of people aged more than 15 who attained an education level of college or above.

All-cause and cause-specific standardized mortality ratios (SMRs) were obtained by employing the personal computer version of Life Table Analysis System (LTAS.NET). The LTAS was originally developed by the National Institute for

Occupational Safety and Health (NIOSH) during the 1970s and was later converted for use on Windows 98/NT/2000/XP-compatible PCs. This program tabulates the underlying causes of death as well as the person-years of follow-up into age-, gender-, and race-specific strata, and allows users to apply internal controls as referents to replace general population from vital statistics. SMRs and 95% confidence intervals (CIs) were calculated using the mortality rates of 119 underlying causes of death of the internists of Taiwan as the reference group. We used SAS Version 9.1 (SAS institute) to edit and analyze the data. In this study, we set the significance level at p=0.05.

Cox regression analysis was conducted to determine the hazard ratios for the following risk factors: age, gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice (before or after 1995 when the NHI system was established), and doctor to population ratio. The ratio between doctors and population was categorized into 4 levels: larger than 1:500, from 1:500 to 1:700, from 1:700 to 1:900, and less than 1:900. Since the northern region of Taiwan leads development for the last half a century, it was chosen to be the reference in the statistical model. The covariates considered in the regression analysis were gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice, and doctor to population ratio. In Taiwan, some of our doctors were veteran who took ad-hoc medical missions during the world II and did not receive an academic medical education. They generally began their practices at an age older than most other doctors and deserved for this study to control as a potential confounder. We applied the stepwise strategy for variable selection with the significance level for entry and the significance level for stay set to 0.15. Regression diagnostics were also run, including examination of proportional hazard assumption, residual analysis, detection of influential cases, and check for multi-co-linearity to

assure the quality of analysis and goodness of fit for the model.

Results

With the doctor to population ratio above 1:500 as the reference level, we found that a lower ratio significantly increased the hazard ratio (HR) of doctor mortality; there was also an independent effect of regional difference of higher HR for southern and eastern regions, as summarized in Table 4. The differences among localities seemed to correlate well with higher average levels of income and education, lower infant mortality rates, and longer life expectancies across Taiwan. And such disparities did not appear to have changed during the last decade (Table 1).

A total of 37,545 doctors were tabulated in the study from January 1990 to December 2006. During the above period, there were 1642 deaths among 32,713 male doctors and 44 deaths among 4822 female doctors. The overall mean age at death was 69.88± 14.28 years old, with 70.06±14.04 for males and 62.96±20.21 for females, respectively. (Table 2) Approximately half (49.7%) of the cohort had been internists, 48.1% were practicing in the north region. Among all doctors, there were 30.8% working in the area of low doctor to population ratio. About two-thirds began their practice before 1995, and over 90% started practice at age below 40.

As for the control for socioeconomic status in the analysis, we used the internists as the reference population and found that the all cause specific SMRs for surgeons and anesthesiologists were marginally elevated with an SMR of 1.15 (95% CI: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64), respectively (Table 3). Among the surgeons, the SMR of "Neoplasm of lymphatic and hematopoietic tissue" was increased but without statistical significance (SMR = 2.17, 95% CI: 0.94 to 4.28). The observed numbers of deaths from malignant neoplasm of digestive organs and peritoneum were significantly lower than corresponding expected values (SMR =0.54, $p < 0.05$, 95% CI: 0.29 to 0.92). Among the anesthesiologists, the SMR of "malignant neoplasm of other and unspecified sites" was significantly increased (SMR =8.73, $p < 0.05$, 95%

CI: 1.06 to 31.53), although there were only 2 cases on the observed number.

To further adjust for other risk factors, the Cox regression model was constructed and the results were summarized in Table 4. The anesthesiologists appeared to show the highest hazard ratios (HRs) of 1.97 (95% CI, 1.20 to 3.25), followed by surgeons with a HR of 1.23 (95%CI, 1.04 to 1.46). The HR of ophthalmologists was significantly lower than all other specialists, of which the HR was 0.72 (95%CI, 0.53 to 0.98). In addition, doctors living in the northern region and the central region experienced lower HR's. And doctors who worked in the area with doctor to population ratio below 1:500 showed higher mortality or HR.

The doctors who began practice at an older age had a higher HR of 1.12 (95%CI, 1.12 to 1.13) for every single year increment. Overall, doctors who began practice after the implementation of NHI Program, or the year of 1995, showed a higher HR of 6.17 (95%CI, 4.27 to 8.92).

Discussion

Based on Cox's Model analysis, we found doctors practicing in southern and eastern regions of Taiwan suffered from statistically significant premature mortality (Table 4), and such a geographic disparity appeared to correspond to the lower life expectancy and higher infant mortality rate in Taiwan (Table 1). To our limited knowledge, this study is the first to show that doctors practicing in the area of a low doctor to population ratio or in the less resourceful regions experienced a higher HR of mortality after adjustment for gender, age of beginning practice, and specialties (Table 4). Because doctors in Taiwan generally have higher earnings than all other segments of professionals and there is no upper limit of retirement age, we have decided to select "internal comparisons" among doctors with the same socioeconomic status, profession-related knowledge and health-related behaviour, to prevent confounding and would leave the effects of mortality to the other two main factors, occupational workload or practice environment. In additional to internists, we have tried to use surgeons as a possibly more homogeneous reference group and the hazard ratios of all covariates are the same except those of specialties, demonstrating a robust result for our inference.

Lowest average income, educational level and life expectancy, and the highest infant mortality rate in Taiwan were found in the eastern region (Table 1). Traditionally, this mountainous region impedes transportation tremendously, and plays a significant role in reduced healthcare accessibility for people, including health care providers themselves. Although the doctor to population ratio has improved since the promulgation of Medical Care Act in 1986 and implementation of NHI in 1995, doctors living in this region still suffer from a higher HR. It may indicate that the health disparity still exists. Moreover, in analyzing the central and southern regions, where similar levels of the average income and the education were found, a significantly increased hazard ratio was detected in the southern region only. As noted in Table 1, the doctor to population ratio has been consistently found to be lower in the southern region compared with those of the northern and central regions. These findings indicate persistent health disparities in different regions of Taiwan, and suggest that occupational workloads might play some role in view of the increased mortality of doctors.

In a previous study, we found that the overall and cause-specific SMRs of doctors in Taiwan were less than 0.34 for different specialties[11], which may have been confounded by using the general population as the referents for comparison[16]. In this study, we use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states (Table 3). Although no increased mortality was found among radiologists, pathologists, and psychiatrists, as reported from other countries[2-4], we detected significantly increased HRs for surgeons and anesthesiologists (Table 4). A further analysis only detected slightly elevated SMR for malignant neoplasm of lymphatic and hematopoietic tissues among surgeons, which appeared to corroborate the hazards of operation room reported by others[17]. However, the trend was less apparent because of the small sample size of anesthesiologists. Since the current mortality data in Taiwan only allowed for coding single underlying cause of death, it may further decrease the power of detection of occupational related illnesses.

Our study also demonstrated the HR of mortality was higher in the group beginning their practice since 1995, when the National Health Insurance system was implemented. This group belonged to a younger generation of doctors, who might possibly suffer from highly stressed work during their practice[18]. Such a stress might arise from their clinical training program or the newly implemented health policy. However, the cohort was established during 1990-2006, which may have imposed a selection of healthy survivors among the doctors. They began their practice before 1995 in comparison with those who entered the workforce after 1995. Thus, more study is needed to explore the above hypothesis.

Several limitations of this study should be noted. Firstly, possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties. For instance, a surgeon shifted to general practice after retiring from a medical center may result in overestimation of the practice duration and possible underestimation of the effect of specialty. Thus, the higher HR's among surgeons and anesthesiologists may need to be further studied for clarification. Secondly, information was limited about the hospital level and the locations which the doctor has practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

In conclusion, disparities both in the geographic region of doctor's practice and the ratio of doctor to population regionally are the primary determinants to the HR of doctor mortality. Thus, we recommend increasing the number of doctors and improving the practice environment of eastern and southern regions of Taiwan, which may possibly mitigate the health disparities among doctors and people. Further, more studies are needed to explore and reduce the potential hazards among workplaces of anesthesiologists and surgeons in Taiwan.

Acknowledgements

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Contribution statement

The first author, Dr. Tung-Fu Shang, has acquired the dataset, designed the study together with Dr. Wang (the corresponding author), conducted the analysis under the full supervision and discussion with Drs. Chen and Wang, written the first draft, and all three participated in the revision of the later drafts until the final one.

Dr. Shang has access to all the data in the study and takes responsibility for the integrity of the data. Together with all co-authors, we shall be responsible for the accuracy of the data analysis, interpretation of the results.

Competing interests:

All authors of this manuscript indicate no conflicts of interest and have complied with the Principles of Ethical Practice of Public Health. The Ethics Review Board of our institute (Institute of Occupational Medicine and Industrial Hygiene College of Public Health, National Taiwan University, Taiwan) approved the protocol before the commencement of this study.

Funding

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Data Sharing

We are willing to share our data in an open reposittory.

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Table 1 -- Geographic disparities in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth in 1998, 2002, and 2006.

Region	Doctors per 10,000 persons			Per capita disposable income			Education §			Infant mortality rate			Life expectancy		
	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006
Northern	14.7	16.5	17.4	8394.8	8912.6	9853.0	24.8	30.1	36.1	6.2	4.9	4.4	77.4	78.6	79.5
Central	14.1	16.5	18.3	7044.2	6940.0	7817.6	18.8	23.2	28.6	6.9	5.8	4.5	75.1	77.0	77.6
Southern	12.9	14.5	16.5	6928.8	7157.5	7891.2	18.4	22.8	27.7	6.4	5.4	4.8	74.7	76.0	76.5
Eastern	13.3	15.4	18.3	6542.2	6683.0	7987.6	11.8	14.4	20.0	12.4	8.3	7.6	70.6	72.9	73.2

§**Education**: The percentage of people aged more than 15 attained an education level of college or above

Table 2 -- Characteristics of Taiwan doctors included in the study from 1990 to 2006.

	Taiwan doctors		Deceased doctors	
	No. (%)	mean censored age	No. (%)	mean age at death
Total	37,545 (100)	46.41±14.47	1686 (100)	69.88±14.28
Status				
Alive	35,859 (95.5)	45.31±13.51		
Deceased	1686 (4.5)			69.88±14.28
Sex				
Male	32,722 (87.2)	47.68±14.56	1642 (97.4)	70.06±14.04
Female	4823 (12.8)	37.81±10.30	44 (2.6)	62.96±20.21
Age of beginning practice				
age<30	29,753 (79.2)	43.39±11.99	566 (33.6)	59.03±14.98
30<=age<40	5573 (14.8)	52.28±14.10	472 (28.0)	73.81±11.92
age≧40	2219 (5.9)	74.24±10.91	648 (38.4)	76.37±8.62
Specialty				
Surgeon	4571 (12.2)	45.20±13.20	161 (9.5)	65.83±14.54
Internist	18,664 (49.7)	48.76±15.97	1190 (70.1)	71.92±12.70
Dermatologist	901 (2.4)	43.00±12.92	35 (2.1)	69.79±16.25
Otolaryngologist	2000 (5.3)	44.28±11.99	45 (2.7)	65.46±14.36
Ophthalmologist	1584 (4.2)	44.72±12.33	42 (2.5)	72.28±19.56
Pathologist	414 (1.1)	42.21±12.04	5 (0.3)	49.78±10.87
Pediatrician	2883 (7.7)	42.35±11.59	54 (3.2)	66.32±17.12

Psychiatrist	1214 (3.2)	40.37±11.81	21 (1.2)	61.85±20.52
Radiologist	1076 (2.9)	41.59±11.79	18 (1.1)	63.23±18.18
Obstetrician	2278 (6.1)	48.84±12.10	85 (5.0)	63.48±14.44
Orthopedist	1128 (3.0)	43.56±11.07	14 (0.8)	58.78±18.32
Anesthesiologist	832 (2.2)	40.91±10.23	16 (0.9)	45.21±15.67
Region				
Northern	18,046 (48.1)	45.71±14.52	659 (39.1)	68.90±14.32
Central	7054 (18.8)	46.25±13.70	300 (17.8)	70.04±15.58
Southern	11,376 (30.3)	47.64±14.81	667 (39.6)	70.97±13.57
Eastern	1069 (2.8)	46.24±14.12	60 (3.6)	67.67±13.96
Doctor-population ratio				
＞1：500	17,185 (45.8)	45.29±14.34	620 (36.8)	68.21±15.11
1：700 to 1：500	6429 (17.1)	45.55±14.50	285 (16.9)	69.71±14.19
1：900 to 1：700	11,233 (29.9)	47.91±14.21	589 (34.9)	70.92±13.61
＜1：900	2698 (7.2)	51.08±14.53	192 (11.4)	71.90±13.02
Years of practice				
Before 1995	24,337 (64.8)	53.62±12.71	1640 (97.3)	70.60±13.52
After 1995	13,208 (35.2)	33.13±5.06	46 (2.7)	44.28±16.86

Table 3 -- The observed number of deaths and cause specific SMRs (standardized mortality ratios) for surgeons and anesthesiologists, using internists of Taiwan as the reference group.

	Surgeon			Anesthesiologist		
Causes of death	**O**	**SMR**	**95%CI** [§]	**O**	**SMR**	**95%CI**
All causes	161	1.15	(0.98 - 1.34)	16	1.62	(0.93 - 2.64)
All malignant neoplasm (MN)	37	0.84	(0.59 - 1.16)	5	1.57	(0.51 - 3.66)
MN of digestive organs and peritoneum	13	0.54	(0.29 -0.92)	2	1.18	(0.14 -4.26)
MN of respiratory system	11	1.16	(0.58 - 2.07)	0	0.00	(0.00- 6.56)
MN of urinary organs	2	1.05	(0.13 - 3.79)	0	0.00	(0.00 - 20.42)
Neoplasm of lymphatic and hematopoietic tissue	8	2.17	(0.94 - 4.28)	1	3.41	(0.09 -19.03)
MN of other and unspecified sites	1	0.48	(0.01 -2.68)	2	8.73	(1.06 - 31.53)
Cerebrovascular disease	7	0.59	(0.24 - 1.22)	3	3.95	(0.82 - 11.55)
Heart disease	9	0.83	(0.38 -1.57)	0	0.00	(0.00 - 7.34)
Accidents	11	1.81	(0.90 -3.24)	1	1.58	(0.04 - 8.79)
Diabetes mellitus	8	1.49	(0.65 -2.94)	1	1.84	(0.05 -10.25)
Chronic liver disease	7	1.60	(0.64 -3.30)	0	0.00	(0.00 -13.75)
Kidney disease	1	0.36	(0.01 -2.01)	0	0.00	(0.00 -21.26)
Pneumonia	5	0.97	(0.32 - 2.27)	0	0.00	(0.00 -12.23)
Suicide	3	1.36	(0.28 - 3.98)	1	3.34	(0.08 -18.60)

Chronic lung disease	4	2.19	(0.60 - 5.60)	0	0.00	(0.00 -116.04)
Hypertensive disease	2	1.45	(0.18 - 5.25)	0	0.00	(0.00 - 30.76)

[§] **CI: confidence interval**

Table 4 -- Hazard ratios with 95% CI (confidence interval) estimated through Cox regression model to control relevant risk factors on mortality among Taiwan doctors from 1990 to 2006.

Covariate	Hazard ratio	95% CI
Age of beginning practice		
	1.12	1.12-1.13
Gender		
Female/male	0.76	0.56-1.02
Specialty		
Dermatologist / Internist	1.19	0.85-1.67
Otolaryngologist / Internist	0.85	0.63-1.15
Ophthalmologist / Internist	0.72	0.53-0.98
Pathologist/ Internist	0.81	0.33-1.94
Pediatrician / Internist	0.91	0.69-1.20
Psychiatrist / Internist	0.81	0.52-1.24
Radiologist / Internist	0.87	0.55-1.39
Surgeon / Internist	1.23	1.04-1.46
Obstetrician / Internist	1.19	0.95-1.50
Orthopedist / Internist	0.75	0.44-1.27
Anesthesiologists/ Internist	1.97	1.20-3.25
Region		
Central / Northern	1.12	0.97-1.29
Southern / Northern	1.30	1.17-1.45
Eastern / Northern	1.68	1.28-2.20
Doctor-population ratio		

1：700 to 1：500 / ＞1：500	1.23	1.06-1.42
1：900 to 1：700 / ＞1：500	1.20	1.06-1.34
＜1：900 / ＞1：500	1.18	1.00-1.39
Year of beginning practice		
After 1995/ Before1995	6.17	4.27-8.92

WHAT IS ALREADY KNOWN ON THIS TOPIC

All factors leading to health disparities are affecting people within respective locality.

WHAT THIS STUDY ADDS

All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.

Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Disparities in Mortality among Doctors in Taiwan:

A 17-year follow-up study of 37,545 Doctors

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Objectives. We used cohort data from the registry of all doctors in Taiwan to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Design. Retrospective cohort study, 1990-2006.

Settings. The Taiwan Medical Association (TMA).

Participants. A total of 37,545 doctors from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors.

Main outcome measures. Cause-specific standardized mortality ratios (SMRs) for surgeons and anesthesiologists were compared to those of the internists. Cox's proportional hazard model was constructed to explore multiple risk factors for mortality, including specialties, age, gender, geographic region of practices, regional health resources, ages of beginning practices, and years of beginning practice.

Results. The all-cause specific SMRs for surgeons and anesthesiologists were marginally elevated at 1.15 (95% confidence interval: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64) respectively. The Cox regression model showed that the anesthesiologists had the highest hazard ratio (HR) of 1.97, seconded by surgeons at 1.23. Localities with the doctor to population ratio lower than 1:500 were associated with an increased HR of doctor mortality.

Conclusions. The doctor to population ratio and the region of practice may influence doctor's mortality. Increasing number of doctors and/or improving the practice environment may be helpful in reducing the health disparities in regions with poor resources.

Article Summary

Article focus

To determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Key messages

- All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.
- Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Strengths and limitations of this study

Strengths

- The cohort data includes all practicing doctors in Taiwan.
- We use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states.

Limitations

- Possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties.
- Information was limited about the hospital level and location practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting.

During practices, health care providers have already been noted to suffer from certain specific potential hazards like stress, radiation, anesthetic gases or agents and biologically hazardous blood or body fluids, which have been documented in many previous studies among radiologists, pathologists, psychiatrists, dentists, and anesthesiologists[1-6].

Beginning in 1995, Taiwan launched the National Health Insurance (NHI) program and attempted to mitigate the health disparity among the general population living in different geographic regions. The provision of universal health care coverage has increased the health care demand[7-8]. For example, the number of outpatient visits per person increased from 10.56 in 1995 to 14.88 in 2008, and the numbers of hospitalized patients and outpatient visits per doctor increased as well[9-10]. , Thus, all the healthcare professionals, including doctors, have encountered a heavier workload and a greater psychosocial demand than before. However, a standardized mortality ratio (SMR) study using the general population as the reference for comparison did not detect any increased mortality among doctors in Taiwan[11].

From an alternative perspective, the association between demographic characteristics of human resources in health and the health of the population served has received considerable attention[12-13]. There is a growing evidence that the density of the health workforce is directly correlated with positive health outcomes in the population they serve, such as maternity mortality, infant mortality and life expectancy[14]. Other factors like geographic location, socioeconomic states and distribution of current health care resources might also affect health outcome and incline to inter-correlate with each other.

As all factors leading to health disparities are affecting people within respective locality[15], we hypothesized that they also influence the mortality rates of healthcare providers, including doctors who practiced in such locality. In the present study, we

used the cohort data from the registry of the doctor file maintained by the Taiwan Medical Association (TMA) and recruited internists, the largest group, as referents to determine if the effect of health disparities exists after control of potential confounding by different occupational exposures in different specialties.

Methods

Subjects and data collection

The retrospective cohort was established from the registry of the doctor file maintained by TMA. The registry has been required by the governmental regulation for verification of credentials of all practicing doctors. It contains the name of each individual, date and place of birth, gender, national identification number, medical school attended, date of graduation, self-designated specialty[11], place of practice, vital status, date of death for decedents, and date of ceasing the membership. The cohort was established beginning in January 1990 and followed up to December 2006. Practice time was accrued until 2006, or the date of deceased or termination of membership. There were 29 decedents with incomplete information on date or month of death, of which this study assumed to be on the first day of the month or year. Since all practicing doctors must be registered in compliance to the Doctors Act in Taiwan, the dataset is very comprehensive and accurate.

Statistical analysis

Geographic data in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth were collected and analyzed from national statistics of the Directorate General of Budget, Accounting and Statistics (Taiwan) in 1998, 2002, and 2006. Geographic region was categorized into northern, central, southern and eastern region following the naming of branches of Bureau of National Health Insurance. Education indicated the percentage of people aged more than 15 who attained an education level of college or above.

All-cause and cause-specific standardized mortality ratios (SMRs) were obtained by employing the personal computer version of Life Table Analysis System (LTAS.NET). The LTAS was originally developed by the National Institute for

Occupational Safety and Health (NIOSH) during the 1970s and was later converted for use on Windows 98/NT/2000/XP-compatible PCs. This program tabulates the underlying causes of death as well as the person-years of follow-up into age-, gender-, and race-specific strata, and allows users to apply internal controls as referents to replace general population from vital statistics. SMRs and 95% confidence intervals (CIs) were calculated using the mortality rates of 119 underlying causes of death of the internists of Taiwan as the reference group. We used SAS Version 9.1 (SAS institute) to edit and analyze the data. In this study, we set the significance level at p=0.05.

Cox regression analysis was conducted to determine the hazard ratios for the following risk factors: age, gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice (before or after 1995 when the NHI system was established), and doctor to population ratio. The ratio between doctors and population was categorized into 4 levels: larger than 1:500, from 1:500 to 1:700, from 1:700 to 1:900, and less than 1:900. Since the northern region of Taiwan leads development for the last half a century, it was chosen to be the reference in the statistical model. The covariates considered in the regression analysis were gender, specialty, geographic region of practice, age of beginning practice, calendar year of beginning practice, and doctor to population ratio. In Taiwan, some of our doctors were veteran who took ad-hoc medical missions during the world II and did not receive an academic medical education. They generally began their practices at an age older than most other doctors and deserved for this study to control as a potential confounder. We applied the stepwise strategy for variable selection with the significance level for entry and the significance level for stay set to 0.15. Regression diagnostics were also run, including examination of proportional hazard assumption, residual analysis, detection of influential cases, and check for multi-co-linearity to

assure the quality of analysis and goodness of fit for the model.

Results

With the doctor to population ratio above 1:500 as the reference level, we found that a lower ratio significantly increased the hazard ratio (HR) of doctor mortality; there was also an independent effect of regional difference of higher HR for southern and eastern regions, as summarized in Table 4. The differences among localities seemed to correlate well with higher average levels of income and education, lower infant mortality rates, and longer life expectancies across Taiwan. And such disparities did not appear to have changed during the last decade (Table 1).

A total of 37,545 doctors were tabulated in the study from January 1990 to December 2006. During the above period, there were 1642 deaths among 32,713 male doctors and 44 deaths among 4822 female doctors. The overall mean age at death was 69.88± 14.28 years old, with 70.06±14.04 for males and 62.96±20.21 for females, respectively. (Table 2) Approximately half (49.7%) of the cohort had been internists, 48.1% were practicing in the north region. Among all doctors, there were 30.8% working in the area of low doctor to population ratio. About two-thirds began their practice before 1995, and over 90% started practice at age below 40.

As for the control for socioeconomic status in the analysis, we used the internists as the reference population and found that the all cause specific SMRs for surgeons and anesthesiologists were marginally elevated with an SMR of 1.15 (95% CI: 0.98-1.34) and 1.62 (95% CI: 0.93-2.64), respectively (Table 3). Among the surgeons, the SMR of "Neoplasm of lymphatic and hematopoietic tissue" was increased but without statistical significance (SMR = 2.17, 95% CI: 0.94 to 4.28). The observed numbers of deaths from malignant neoplasm of digestive organs and peritoneum were significantly lower than corresponding expected values (SMR =0.54, $p < 0.05$, 95% CI: 0.29 to 0.92). Among the anesthesiologists, the SMR of "malignant neoplasm of other and unspecified sites" was significantly increased (SMR =8.73, $p < 0.05$, 95%

CI: 1.06 to 31.53), although there were only 2 cases on the observed number.

To further adjust for other risk factors, the Cox regression model was constructed and the results were summarized in Table 4. The anesthesiologists appeared to show the highest hazard ratios (HRs) of 1.97 (95% CI, 1.20 to 3.25), followed by surgeons with a HR of 1.23 (95%CI, 1.04 to 1.46). The HR of ophthalmologists was significantly lower than all other specialists, of which the HR was 0.72 (95%CI, 0.53 to 0.98). In addition, doctors living in the northern region and the central region experienced lower HR's. And doctors who worked in the area with doctor to population ratio below 1:500 showed higher mortality or HR.

The doctors who began practice at an older age had a higher HR of 1.12 (95%CI, 1.12 to 1.13) for every single year increment. Overall, doctors who began practice after the implementation of NHI Program, or the year of 1995, showed a higher HR of 6.17 (95%CI, 4.27 to 8.92).

Discussion

Based on Cox's Model analysis, we found doctors practicing in southern and eastern regions of Taiwan suffered from statistically significant premature mortality (Table 4), and such a geographic disparity appeared to correspond to the lower life expectancy and higher infant mortality rate in Taiwan (Table 1). To our limited knowledge, this study is the first to show that doctors practicing in the area of a low doctor to population ratio or in the less resourceful regions experienced a higher HR of mortality after adjustment for gender, age of beginning practice, and specialties (Table 4). Because doctors in Taiwan generally have higher earnings than all other segments of professionals and there is no upper limit of retirement age, we have decided to select "internal comparisons" among doctors with the same socioeconomic status, profession-related knowledge and health-related behaviour, to prevent confounding and would leave the effects of mortality to the other two main factors, occupational workload or practice environment. In additional to internists, we have tried to use surgeons as a possibly more homogeneous reference group and the hazard ratios of all covariates are the same except those of specialties, demonstrating a robust result for our inference.

Lowest average income, educational level and life expectancy, and the highest infant mortality rate in Taiwan were found in the eastern region (Table 1). Traditionally, this mountainous region impedes transportation tremendously, and plays a significant role in reduced healthcare accessibility for people, including health care providers themselves. Although the doctor to population ratio has improved since the promulgation of Medical Care Act in 1986 and implementation of NHI in 1995, doctors living in this region still suffer from a higher HR. It may indicate that the health disparity still exists. Moreover, in analyzing the central and southern regions, where similar levels of the average income and the education were found, a significantly increased hazard ratio was detected in the southern region only. As noted in Table 1, the doctor to population ratio has been consistently found to be lower in the southern region compared with those of the northern and central regions. These findings indicate persistent health disparities in different regions of Taiwan, and suggest that occupational workloads might play some role in view of the increased mortality of doctors.

In a previous study, we found that the overall and cause-specific SMRs of doctors in Taiwan were less than 0.34 for different specialties[11], which may have been confounded by using the general population as the referents for comparison[16]. In this study, we use internists as the reference population for SMR calculation to minimize the potential confounding by different socioeconomic states (Table 3). Although no increased mortality was found among radiologists, pathologists, and psychiatrists, as reported from other countries[2-4], we detected significantly increased HRs for surgeons and anesthesiologists (Table 4). A further analysis only detected slightly elevated SMR for malignant neoplasm of lymphatic and hematopoietic tissues among surgeons, which appeared to corroborate the hazards of operation room reported by others[17]. However, the trend was less apparent because of the small sample size of anesthesiologists. Since the current mortality data in Taiwan only allowed for coding single underlying cause of death, it may further decrease the power of detection of occupational related illnesses.

Our study also demonstrated the HR of mortality was higher in the group beginning their practice since 1995, when the National Health Insurance system was implemented. This group belonged to a younger generation of doctors, who might possibly suffer from highly stressed work during their practice[18]. Such a stress might arise from their clinical training program or the newly implemented health policy. However, the cohort was established during 1990-2006, which may have imposed a selection of healthy survivors among the doctors. They began their practice before 1995 in comparison with those who entered the workforce after 1995. Thus, more study is needed to explore the above hypothesis.

Several limitations of this study should be noted. Firstly, possible misclassification of self-claimed specialty may be a source of bias while comparing the mortality rates among different specialties. For instance, a surgeon shifted to general practice after retiring from a medical center may result in overestimation of the practice duration and possible underestimation of the effect of specialty. Thus, the higher HR's among surgeons and anesthesiologists may need to be further studied for clarification. Secondly, information was limited about the hospital level and the locations which the doctor has practiced, i.e., misclassification of the region of practice without differentiating primary/referral hospital and urban/rural setting. Thus, we had to assume that it might be a random effect and only lead to the null or under-estimation.

In conclusion, disparities both in the geographic region of doctor's practice and the ratio of doctor to population regionally are the primary determinants to the HR of doctor mortality. Thus, we recommend increasing the number of doctors and improving the practice environment of eastern and southern regions of Taiwan, which may possibly mitigate the health disparities among doctors and people. Further, more studies are needed to explore and reduce the potential hazards among workplaces of anesthesiologists and surgeons in Taiwan.

Acknowledgements

The authors express sincere appreciation to Taiwan Medical Association (TMA) for the maintenance of the relevant database. We also thank Dr. Fu-Chang Hu for his assistance in data analysis using SAS. The study was partially supported by a grant from the National Science Council of the Executive Yuan, Taiwan (No. NSC 99-2628-B-006-036-MY3). The sponsors had no role in the study design, data collection, data analyses, the interpretation of data, the writing of the report, or the decision to submit the article for publication.

Contribution statement

The first author, Dr. Tung-Fu Shang, has acquired the dataset, designed the study together with Dr. Wang (the corresponding author), conducted the analysis under the full supervision and discussion with Drs. Chen and Wang, written the first draft, and all three participated in the revision of the later drafts until the final one.

Dr. Shang has access to all the data in the study and takes responsibility for the integrity of the data. Together with all co-authors, we shall be responsible for the accuracy of the data analysis, interpretation of the results.

Competing interests:

All authors of this manuscript indicate no conflicts of interest and have complied with the Principles of Ethical Practice of Public Health. The Ethics Review Board of our institute (Institute of Occupational Medicine and Industrial Hygiene College of Public Health, National Taiwan University, Taiwan) approved the protocol before the commencement of this study.

Funding

The study was partially supported by a grant from the National Science Council of the Executive Yuan, Taiwan (No. NSC 99-2628-B-006-036-MY3). The sponsors had no role in the study design, data collection, data analyses, the interpretation of data, the writing of the report, or the decision to submit the article for publication.

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Table 1 -- Geographic disparities in doctors per 10,000 persons, per capita disposable income (US$), education, infant mortality rate (per 1000 live births), and life expectancy at birth in 1998, 2002, and 2006.

Region	Doctors per 10,000 persons			Per capita disposable income			Education [§]			Infant mortality rate			Life expectancy		
	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006	1998	2002	2006
Northern	14.7	16.5	17.4	8394.8	8912.6	9853.0	24.8	30.1	36.1	6.2	4.9	4.4	77.4	78.6	79.5
Central	14.1	16.5	18.3	7044.2	6940.0	7817.6	18.8	23.2	28.6	6.9	5.8	4.5	75.1	77.0	77.6
Southern	12.9	14.5	16.5	6928.8	7157.5	7891.2	18.4	22.8	27.7	6.4	5.4	4.8	74.7	76.0	76.5
Eastern	13.3	15.4	18.3	6542.2	6683.0	7987.6	11.8	14.4	20.0	12.4	8.3	7.6	70.6	72.9	73.2

[§]**Education**: The percentage of people aged more than 15 attained an education level of college or above

Table 2 -- Characteristics of Taiwan doctors included in the study from 1990 to 2006.

	Taiwan doctors		Deceased doctors	
	No. (%)	mean censored age	No. (%)	mean age at death
Total	37,545 (100)	46.41±14.47	1686 (100)	69.88±14.28
Status				
Alive	35,859 (95.5)	45.31±13.51		
Deceased	1686 (4.5)			69.88±14.28
Sex				
Male	32,722 (87.2)	47.68±14.56	1642 (97.4)	70.06±14.04
Female	4823 (12.8)	37.81±10.30	44 (2.6)	62.96±20.21
Age of beginning practice				
age<30	29,753 (79.2)	43.39±11.99	566 (33.6)	59.03±14.98
30<=age<40	5573 (14.8)	52.28±14.10	472 (28.0)	73.81±11.92
age≧40	2219 (5.9)	74.24±10.91	648 (38.4)	76.37±8.62
Specialty				
Surgeon	4571 (12.2)	45.20±13.20	161 (9.5)	65.83±14.54
Internist	18,664 (49.7)	48.76±15.97	1190 (70.1)	71.92±12.70
Dermatologist	901 (2.4)	43.00±12.92	35 (2.1)	69.79±16.25
Otolaryngologist	2000 (5.3)	44.28±11.99	45 (2.7)	65.46±14.36
Ophthalmologist	1584 (4.2)	44.72±12.33	42 (2.5)	72.28±19.56
Pathologist	414 (1.1)	42.21±12.04	5 (0.3)	49.78±10.87
Pediatrician	2883 (7.7)	42.35±11.59	54 (3.2)	66.32±17.12

Psychiatrist	1214 (3.2)	40.37±11.81	21 (1.2)	61.85±20.52
Radiologist	1076 (2.9)	41.59±11.79	18 (1.1)	63.23±18.18
Obstetrician	2278 (6.1)	48.84±12.10	85 (5.0)	63.48±14.44
Orthopedist	1128 (3.0)	43.56±11.07	14 (0.8)	58.78±18.32
Anesthesiologist	832 (2.2)	40.91±10.23	16 (0.9)	45.21±15.67
Region				
Northern	18,046 (48.1)	45.71±14.52	659 (39.1)	68.90±14.32
Central	7054 (18.8)	46.25±13.70	300 (17.8)	70.04±15.58
Southern	11,376 (30.3)	47.64±14.81	667 (39.6)	70.97±13.57
Eastern	1069 (2.8)	46.24±14.12	60 (3.6)	67.67±13.96
Doctor-population ratio				
＞1：500	17,185 (45.8)	45.29±14.34	620 (36.8)	68.21±15.11
1：700 to 1：500	6429 (17.1)	45.55±14.50	285 (16.9)	69.71±14.19
1：900 to 1：700	11,233 (29.9)	47.91±14.21	589 (34.9)	70.92±13.61
＜1：900	2698 (7.2)	51.08±14.53	192 (11.4)	71.90±13.02
Years of practice				
Before 1995	24,337 (64.8)	53.62±12.71	1640 (97.3)	70.60±13.52
After 1995	13,208 (35.2)	33.13±5.06	46 (2.7)	44.28±16.86

Table 3 -- The observed number of deaths and cause specific SMRs (standardized mortality ratios) for surgeons and anesthesiologists, using internists of Taiwan as the reference group.

	Surgeon			Anesthesiologist		
Causes of death	**O**	**SMR**	**95%CI** §	**O**	**SMR**	**95%CI**
All causes	161	1.15	(0.98 - 1.34)	16	1.62	(0.93 - 2.64)
All malignant neoplasm (MN)	37	0.84	(0.59 - 1.16)	5	1.57	(0.51 - 3.66)
MN of digestive organs and peritoneum	13	0.54	(0.29 -0.92)	2	1.18	(0.14 -4.26)
MN of respiratory system	11	1.16	(0.58 - 2.07)	0	0.00	(0.00- 6.56)
MN of urinary organs	2	1.05	(0.13 - 3.79)	0	0.00	(0.00 - 20.42)
Neoplasm of lymphatic and hematopoietic tissue	8	2.17	(0.94 - 4.28)	1	3.41	(0.09 -19.03)
MN of other and unspecified sites	1	0.48	(0.01 -2.68)	2	8.73	(1.06 - 31.53)
Cerebrovascular disease	7	0.59	(0.24 - 1.22)	3	3.95	(0.82 - 11.55)
Heart disease	9	0.83	(0.38 -1.57)	0	0.00	(0.00 - 7.34)
Accidents	11	1.81	(0.90 -3.24)	1	1.58	(0.04 - 8.79)
Diabetes mellitus	8	1.49	(0.65 -2.94)	1	1.84	(0.05 -10.25)
Chronic liver disease	7	1.60	(0.64 -3.30)	0	0.00	(0.00 -13.75)
Kidney disease	1	0.36	(0.01 -2.01)	0	0.00	(0.00 -21.26)
Pneumonia	5	0.97	(0.32 - 2.27)	0	0.00	(0.00 -12.23)
Suicide	3	1.36	(0.28 - 3.98)	1	3.34	(0.08 -18.60)

Chronic lung disease	4	2.19	(0.60 - 5.60)	0	0.00	(0.00 -116.04)
Hypertensive disease	2	1.45	(0.18 - 5.25)	0	0.00	(0.00 - 30.76)

[§] **CI: confidence interval**

Table 4 -- Hazard ratios with 95% CI (confidence interval) estimated through Cox regression model to control relevant risk factors on mortality among Taiwan doctors from 1990 to 2006.

Covariate	Hazard ratio	95% CI
Age of beginning practice		
	1.12	1.12-1.13
Gender		
Female/male	0.76	0.56-1.02
Specialty		
Dermatologist / Internist	1.19	0.85-1.67
Otolaryngologist / Internist	0.85	0.63-1.15
Ophthalmologist / Internist	0.72	0.53-0.98
Pathologist/ Internist	0.81	0.33-1.94
Pediatrician / Internist	0.91	0.69-1.20
Psychiatrist / Internist	0.81	0.52-1.24
Radiologist / Internist	0.87	0.55-1.39
Surgeon / Internist	1.23	1.04-1.46
Obstetrician / Internist	1.19	0.95-1.50
Orthopedist / Internist	0.75	0.44-1.27
Anesthesiologists/ Internist	1.97	1.20-3.25
Region		
Central / Northern	1.12	0.97-1.29
Southern / Northern	1.30	1.17-1.45
Eastern / Northern	1.68	1.28-2.20
Doctor-population ratio		

1：700 to 1：500 / ＞1：500	1.23	1.06-1.42
1：900 to 1：700 / ＞1：500	1.20	1.06-1.34
＜1：900 / ＞1：500	1.18	1.00-1.39
Year of beginning practice		
After 1995/ Before1995	6.17	4.27-8.92

WHAT IS ALREADY KNOWN ON THIS TOPIC

All factors leading to health disparities are affecting people within respective locality.

WHAT THIS STUDY ADDS

All factors leading to health disparities also influence the mortality rates of healthcare providers, including doctors who practiced in such locality.

Increasing the numbers of doctors and/or improving the practice environment may be helpful in reducing the health disparities of both the general public and doctors residing in a region with poor resources.

Dear Sir or Madam,

Attached please find our revised manuscript entitled "**Disparities in Mortality among Doctors in Taiwan: A 17-year follow-up study of 37,545 Doctors**" (Manuscript ID bmjopen-2011-000382 R1) for your consideration to be published on your esteemed journal.

My colleagues and I are very grateful to your constructive comments and advice. Please also kindly express our sincere thankfulness and appreciation to all participating reviewers. My research team has a thorough discussion and has made some revision on this version plus point-to-point responses to every comment that you have made.

Thank you. We are looking forward to hearing from you soon.

Yours sincerely,

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RESPONSE TO THE REVIEWER

<u>For Reviewer</u>

Comment # 1

They choose to keep the large group of internal medicine doctors as the reference in their statistical models, the argument for this being htat this is the largest group. However, it is clear from other comments that this is also a very heterogeneous group, so I still maintain that it might be better to use a more homogeneous group for reference, alternatively to choose another contrast function.

Response: Thanks for your comments. We have followed your advice and decided to use a more homogeneous group, surgeons, as the referent alternatively in the Cox regression model. The results appear the same (i.e., all hazard ratios of covariates except those of specialties) and summarized in the following table:

Table. Hazard ratios with 95% CI (confidence interval) estimated through Cox regression model to control relevant risk factors on mortality among Taiwan doctors from 1990 to 2006.

Covariate	Hazard ratio	95% CI
Age of beginning practice		
	1.12	1.12-1.13
Gender		
Female/male	0.76	0.56-1.02
Specialty		
Internist / Surgeon	0.81	0.69-0.96
Dermatologist / Surgeon	0.97	0.67-1.40
Otolaryngologist / Surgeon	0.69	0.49-0.96

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Ophthalmologist / Surgeon	0.59	0.42-0.83
Pathologist/ Surgeon	0.65	0.27-1.59
Pediatrician / Surgeon	0.74	0.54-1.01
Psychiatrist / Surgeon	0.65	0.41-1.03
Radiologist / Surgeon	0.71	0.43-1.15
Obstetrician / Surgeon	0.97	0.74-1.26
Orthopedist / Surgeon	0.61	0.35-1.05
Anesthesiologists/ Surgeon	1.60	0.96-2.69
Region		
Central / Northern	1.12	0.97-1.29
Southern / Northern	1.30	1.17-1.45
Eastern / Northern	1.68	1.28-2.20
Doctor-population ratio		
1：700 to 1：500 / ＞1：500	1.23	1.06-1.42
1：900 to 1：700 / ＞1：500	1.20	1.06-1.34
＜1：900 / ＞1：500	1.18	1.00-1.39
Year of beginning practice		
After 1995/ Before1995	6.17	4.27-8.92

Please kindly see the revised 1st paragraph of the Discussion section, as follows: (Please see page 11, ll. 9-17)

(Table 4). Because doctors in Taiwan generally have higher earnings than all other segments of professionals and there is no upper limit of retirement age, we have decided to select “internal comparisons” among doctors with the same socioeconomic status, profession-related knowledge and health-related behaviour, to prevent confounding and would leave the effects of mortality to the other two main factors, occupational workload or practice environment. In additional to internists, we have tried to use surgeons as a possibly more homogeneous reference group and the hazard ratios of all covariates are the same except those of specialties, demonstrating a robust result for our inference.

3/3

Comment # 2

I still have problems with understanding how the Taiwanese doctors work in relation to hospitals; are all doctors affiliated with hospitals? Don't you have any "real" general practitioners who only work only in their own "surgery" (to use the UK-expression)? And if so, isn't this a group that should be identified in the statistical modelling?

Response: Again, thanks for your comment. Since 1995, Taiwan has implemented mandatory universal health insurance program with a single-payer system. Bureau of national health insurance only contracts with hospitals or clinics and doctors were only allowed to practice at one contracted hospital or run a private clinic. That is a closed system and it comes up with the lowest administration cost of health care in the world (at less than 2% of the total premium). Generally, surgeons as well as anesthesiologists in Taiwan must choose hospital as a workplace to perform major operations, rather than own a clinic. In other words, we do not have general practitioners who can undertake major operations outside hospitals. And family doctors or general practitioners in Taiwan usually open their clinics after their residency training in hospitals and they are included in the internists group.

As my response to your first comment, I have re-run the statistical analysis with surgeons as a more homogeneous reference group and the results appear the same.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			**4-5**
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			**6-7**
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6-7
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			8-9

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9
		(*b*) Report category boundaries when continuous variables were categorized	8-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-9
Discussion			10-11
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations			11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11-12
Other information			13
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.