Journal of Microbiology, Immunology and Infection (2014) 47, 297—303

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ORIGINAL ARTICLE

Employing infectious disease physicians affects clinical and economic outcomes in regional hospitals: Evidence from a population-based study

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Received 21 June 2012; received in revised form 19 December 2012; accepted 25 January 2013
Available online 21 March 2013

KEYWORDS
Antibiotic prescriptions;
Infectious disease physicians;
Regional hospitals;
Total medical expenses;
Treatment outcomes

Background/Purpose: Infectious disease physicians (IDPs) play a major role in patient care, infectious disease control, and antibiotic use in hospitals. The aim of this research is to explore the effects of employment of IDPs on patients' prognosis and the related medical and antibiotic expenses in hospitals.
Methods: This population-based study provides evidence-based information on IDPs' contribution to patients' prognosis and antibiotic expenditure containment with inpatient claim data from the Taiwan Bureau of National Health Insurance in 2004. We further classified regional hospitals into those with and without IDPs and analyzed patient prognosis, length of stay, total medical expenses, and antibiotic expenses to test the effects of IDPs.
Results: The likelihood of developing a poor prognosis among patients was found to be higher in non-IDP hospitals, with an odds ratio of 1.14 and a 95% confidence interval of 1.05—1.23 ($p = 0.002$). Medical expenses, excluding those of nonrestricted drugs, were found to be

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http://dx.doi.org/10.1016/j.jmii.2013.01.010

higher in the non-IDP group than in the IDP group. The total medical expenses were also found to be 10% higher in the non-IDP group than in the IDP group ($p < 0.001$).
Conclusion: Employment of IDPs was likely to improve patient prognosis and reduce overall medical expenses. It is suggested that healthcare administrators consider the employment of or investment in IDPs as a cost-effective strategy for improving patient quality of care.

Introduction

The major responsibilities of infectious disease physicians (IDPs) are patient care, nosocomial infection control, antibiotic management, and infectious disease education and consultation.[1] However, it is difficult to quantitatively evaluate these responsibilities and the performance and workload of IDPs are not properly evaluated in most healthcare settings. In addition, there are insufficient data for hospital administrators to justify employing IDPs.

IDPs play a role in internal quality control in a medical setting. Previous research has indicated that the contributions of IDPs included their role in maintaining medical quality and reducing hospital medical expenses.[2] The role of IDPs was also revealed by a cost-effectiveness analysis of the placement of these professionals and its effect on the outcomes of clinical care.[3] Studies demonstrated that IDPs tended to discharge patients more easily than general internal medicine practitioners, and they were more likely to prescribe oral instead of injectable antibiotics for patients who were discharged earlier.[4,5] In addition, IDPs could also reduce the likelihood of nosocomial infection through the use of appropriate antibiotics. Nosocomial infections can prolong hospital length of stay (LOS) and increase medical costs.[6] Previous cost—benefit analyses showed infection control programs were beneficial.[7,8] More severely ill patients benefitted the most from infection control programs accompanied by infectious disease specialty consultation.[9] Overall, nosocomial infection control was identified as an important factor to reduce medical costs, LOS, and in-hospital mortality.[6] However, the global effect of IDPs on patients' medical outcomes remains unclear.

Better diagnoses and prognoses for patients treated by IDPs were found in some specific types of infections, such as sepsis,[10] endocarditis,[11] and human immunodeficiency virus/acquired immunodeficiency syndrome.[12] The IDPs were able to modify antibiotic prescriptions and used more specific antibiotics following culture results.[13,14] Therefore, IDPs were more likely to prescribe the correct antibiotics than other specialties.

The employment of IDPs is not universally accepted as beneficial in many healthcare systems due to the uncertain effects on healthcare quality and medical expenses in countries such as Taiwan. However, the uneven employment of IDPs in regional hospitals in Taiwan offers the opportunity to examine their effects. The aim of this research was to explore the effects of employment of IDPs on patient prognoses and related medical and antibiotic expenses in hospitals.

Methods

Database and study samples

The study database is a 5% systematic sample of inpatient claims from the Bureau of National Health Insurance in Taiwan in 2004. A total of 57,829 inpatients in regional hospitals were used as the base study population in this analysis.

Regional hospitals were chosen because of their diverse employment of IDPs, optimal size and number of beds, and homogeneous case mix of patients. Hospitals employing IDPs during the study period, as indicated by insurance claims relating to infectious diseases, were classified as having IDPs. Regional hospitals with service volumes below the 25th percentile or above the 75th percentile were excluded in order to control for the skewness of resource allocation and the employment of IDPs in hospitals with different service volumes. In Taiwan, few small hospitals (below the 25th percentile) but most large hospitals (above the 75th percentile) employ IDPs. The study only included patients 18 years of age or older because the use of antibiotics in adults differs from that in children. We grouped hospitals, which included a total of 26,483 hospitalized patients, into those with and without IDPs. The data from these two groups were analyzed for differences between the groups of hospitals regarding medical expenses, drug expenses, antibiotic expenses, patient treatment outcomes, and LOS.

Variables of interest

In this study, antibiotic prescription was limited to treatment for bacterial infections; antituberculosis, antiviral, antifungal, and parasitic medications were excluded. We also limited the type of antibiotic administration to the oral and injection routes and excluded eye drops, ear fluid, plug agents, and skin cream applications.

The purpose of this study is twofold. The first is to compare basic characteristics, including defined daily dose (DDD), total inpatient beds, and total annual inpatient claims, between hospitals with and without IDPs. DDD is defined as "the assumed average maintenance dose per day for a drug used for its main indication in adults".[15] The second is to compare patients' medical outcomes and medical consumptions between groups with and without IDPs. Disease complexity is represented by the Charlson score that covers 19 comorbidity categories, which are defined using the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) diagnosis codes and are weighted from 1 to 6, on the basis of the relative risk of dying from the condition.[16] The overall complexity score was calculated by adding together all individual complexity scores for a given patient in this study. We defined treatment outcomes using information in the discharge records which described the physical conditions and clinical manifestations of patients. Treatment discharge and transfer to outpatient clinic visits were considered improved outcomes, while death, discharge with critical conditions against medical advice, and transfer to other medical institutions for continuing treatment were considered poor outcomes.

Medical consumptions included LOS and medical expenses, which consisted of total medical expenses, total drug expenses, total antibiotic expenses, oral antibiotic expenses, injected antibiotic expenses, unrestricted antibiotic expenses, and restricted antibiotic expenses.

Statistical analyses

Results for medical expenses and LOS are given as numerical variables with means and standard deviation. Frequency and percentage were used to describe categorical variables such as treatment outcomes.

Medical expenses and LOS were logarithmically transformed due to a right skewed distribution for subsequent statistical analyses. Two independent sample *t* tests were used to compare the difference in continuous variables between study groups. The Wilcoxon rank-sum test was also used to compare the difference in continuous variables without logarithmic transformation between the two study groups. The χ^2 test was applied to examine the association of data with categorical variables in the two hospital groups. Furthermore, a multiple logistic regression and general linear model was used for multivariable analysis on treatment outcomes and on medical consumptions while adjusting for other confounding variables. Regression diagnostics, including residual analysis, outlier diagnosis by Cook distance, and collinearity analysis by variance inflation factor and conditional index, were performed to check the appropriateness of the final regression models.

Statistical Analysis System software version 9.2 for Windows (SAS Institute, Cary, North Carolina, USA) was used for data analyses.

Results

Regional hospital data from national health insurance records in Taiwan were collected for a nationwide evidence-based analysis. In the first phase of the analysis, there were 19 regional hospitals with IDPs (intervention group; IDPs) and 18 regional hospitals without IDPs (control group; non-IDPs). Basic characteristics, including DDD, total inpatients beds, total annual inpatient claims, medical departments, and physicians' age and sex, were compared but no significant differences between the two study groups were found. The DDD was 0.46 ± 0.60 in IDPs and 0.84 ± 1.35 in non-IDPs ($p = 0.29$). The total number of inpatients beds was 1040 ± 456 for IDPs and 925 ± 235 for non-IDPs ($p = 0.34$). The total number of annual inpatient claims was 17,194 ± 3135 and 17,191 ± 3008 in IDPs and non-IDPs, respectively ($p = 1.0$). The distribution of major departments was similar between the two study groups ($p = 1.0$). Physician age was also similar in IDPs and non-IDPs (41.7 ± 7.3 years of age and 41.4 ± 7.3 years of age, respectively; $p = 0.39$). Most of the physicians were male

Table 1 Descriptive characteristics of the study hospitals

Variables	IDPs ($n = 19$)	Non-IDPs ($n = 18$)	p
	Mean ± SD	Mean ± SD	
Defined daily doses (1000 person/d)	0.46 ± 0.60	0.84 ± 1.35	0.29[a]
Total inpatient beds	1040 ± 456	925 ± 235	0.34[b]
Total annual inpatient claims	17,194 ± 3135	17,191 ± 3008	1.00[b]
Medical departments			
Family medicine	18 (6.6%)	18 (7.0%)	1.00
General medicine	19 (7.0%)	18 (7.0%)	
Surgery	19 (7.0%)	18 (7.0%)	
Pediatrics	19 (7.0%)	18 (7.0%)	
Obstetrics and gynecology	19 (7.0%)	18 (7.0%)	
Others[d]	179 (65.6%)	169 (65.3%)	
Physician age	41.7 ± 7.3	41.4 ± 7.3	0.39[b]
Physician sex			
Male	1079 (88.7%)	948 (89.9%)	0.39[c]
Female	137 (11.3%)	107 (10.1%)	

[a] Calculated using the Wilcoxon rank-sum test.
[b] Calculated using a two-sample *t* test.
[c] Calculated using the χ^2 test.
[d] Including departments of orthopedics, neurosurgery, urology, otolaryngology, ophthalmology, neurology, psychiatry, rehabilitation, and plastic surgery.
IDPs = infectious disease physicians; SD = standard deviation.

in the IDP and non-IDP groups (88.7% and 89.9%, respectively; $p = 0.39$) (Table 1).

In the second phase of analysis, 13,768 patients and 12,715 patients were included in the IDP and non-IDP groups, respectively. Average patient age was 54.0 years and 55.1 years in the IDP and non-IDPs groups, respectively ($p < 0.001$). There were similar proportions of male and female patients in the two groups ($p = 0.53$). The percentage of patients with poor treatment outcomes was higher in the non-IDP group, (13.24%) than in the IDP group (11.66%; $p < 0.001$). Analysis of the Charlson score found more patients in the IDP group than in the non-IDP group had a higher score ($p < 0.001$). Antilogarithmic transformation showed the total medical expenses per patient were 819.6 USD in IDPs and 914.9 USD in non-IDPs ($p < 0.001$). Furthermore, the non-IDPs group had significantly higher expenses for items such as antibiotics, oral antibiotics, injectable antibiotics, and restricted antibiotics (Table 2).

The likelihood of developing poor treatment outcomes among patients was found to be higher in non-IDP hospitals with an odds ratio (OR) of 1.14 and a 95% confidence interval (CI) of 1.05–1.23 ($p = 0.002$). An increased likelihood of developing poor treatment outcomes was found in the non-IDP group as opposed to the IDP group among the strata of patients age 18–65 years (OR = 1.22, $p < 0.001$), Charlson score = 0 (OR = 1.44, $p < 0.001$) (Table 3).

The medical expenses of patients in the two hospital groups were analyzed using a general linear model. Medical expenses, excluding nonrestricted drugs, were generally higher in the non-IDP group than in the IDP group. Antilogarithmic transformation showed that the total medical expenses per patient were 713.5 USD in the non-IDP group, which is higher than the 641.7 USD in the IDP group ($p < 0.001$). The antilogarithmically transformed overall drug expenses and restricted drug expenses were found to be higher in the non-IDP group than in the IDP group (55.8 USD vs. 55.3 USD, $p < 0.01$; 0.32 USD vs. 0.27 USD, $p < 0.001$, respectively). However, the unrestricted drug expenses were found to be higher in the IDP group than in the non-IDP group (1.2 USD vs. 1.1 USD; $p < 0.01$) (Fig. 1).

Table 2 Demographics, clinical variables, and medical consumptions of patients in the two study groups

	IDPs group	Non-IDPs group	p	p^e
Study patients, *n*	13,768	12,715		
Average patient age[d]	54.0 ± 19.9	55.1 ± 19.9	<0.001[b]	
Patient sex			0.53[c]	
Male	7169 (52.07%)	6567 (51.65%)		
Female	6494 (47.17%)	6062 (47.68%)		
Unreported	105 (0.76%)	86 (0.68%)		
Treatment outcomes			<0.001[c]	
Poor	1605 (11.66%)	1684 (13.24%)		
Improved	12,163 (88.34%)	11,031 (86.76%)		
Charlson score			<0.001[c]	
0	7323 (53.19%)	7003 (55.08%)		
1	2302 (16.72%)	2398 (18.86%)		
2	2143 (15.57%)	1647 (12.95%)		
≥3	2000 (14.53%)	1667 (13.11%)		
Total medical expenses (USD)[e]	819.6 ± 0.2	914.9 ± 0.1	<0.001[a]	0.009
Median (Q1, Q3)	925.8 (524.5, 1737.1)	908.4 (504.9, 1678.8)		
Drug expenses (USD)[e]	61.5 ± 0.2	63.36 ± 0.2	0.25[a]	<0.001
Median (Q1, Q3)	70.4 (25.9, 200.9)	64.4 (24.4, 181.2)		
Antibiotic expenses (USD)[e]	2.4 ± 1.3	2.7 ± 1.4	0.01[a]	0.003
Median (Q1, Q3)	6.8 (0.0, 55.6)	8.5 (0.0, 62.4)		
Oral antibiotic expenses (USD)[d]	0.24 ± 0.4	0.26 ± 0.4	0.05[a]	0.08
Median (Q1, Q3)	0.0 (0.0, 3.0)	0.0 (0.0, 3.0)		
Injectable antibiotic expenses (USD)[d]	1.52 ± 1.5	1.71 ± 1.6	0.007[a]	0.003
Median (Q1, Q3)	3.4 (0.0, 50.8)	3.5 (0.0, 57.2)		
Unrestricted antibiotic expenses (USD)[d]	1.42 ± 1.0	1.39 ± 1.0	0.66[a]	0.60
Median (Q1, Q3)	3.7 (0.0, 37.8)	3.4 (0.0, 36.1)		
Restricted antibiotic expenses (USD)[d]	0.12 ± 0.7	0.16 ± 0.9	<0.001[a]	<0.001
Median (Q1, Q3)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)		
Length of stay[d]	9.1 ± 12.5	9.0 ± 12.4	0.72[a]	0.73
Median (Q1, Q3)	5 (3, 10)	5 (3, 10)		

[a] Calculated by a two-sample *t* test after logarithmic transformation.
[b] Calculated by a two-sample *t* test.
[c] Calculated by the χ^2 test.
[d] Mean ± standard deviation USD.
[e] Calculated by the Wilcoxon rank-sum test.
IDPs = infectious disease physicians; Q=quartile.

Table 3 Patient treatment outcomes between IDP and non-IDP groups stratified by various factors with multiple logistic regression analyses

Sample	Poor	Improved	Odds ratio[a]	95% CI of OR	*p*
Overall patients					
Non-IDP/IDP	1684/1605 (13.2%/11.7%)	11,031/12,163 (86.8%/88.3%)	1.14	1.05,1.23	0.002
Patient characteristics					
Patient age older than 18 y, younger than 65 y					
Non-IDP/IDP	866/853 (10.9%/9.5%)	7062/8157 (89.1%/90.5%)	1.22	1.09,1.36	<0.001
Patient age 65 y or older					
Non-IDP/IDP	818/752 (17.1%/15.8%)	3969/4006 (82.9%/84.2%)	1.08	0.96,1.21	0.23
Patient disease complexity index					
Charlson score = 0					
Non-IDP/IDPs	749/584 (10.7%/7.8%)	6254/6739 (89.3%/92.0%)	1.44	1.27,1.64	<0.001
Charlson score = 1					
Non-IDP/IDP	377/325 (15.7%/14.1%)	2021/1977 (84.3%/85.9%)	1.19	1.00,1.41	0.06
Charlson score ≥ 2					
Non-IDP/IDP	558/696 (16.8%/16.8%)	2756/3447 (83.2%/83.2%)	0.90	0.79,1.03	0.13

[a] Adjusted using patient age, sex, major diagnosis, Charlson score, length of stay, hospital service volume, physician age, and physician sex other than the stratified variable.
CI = confidence interval; IDP = infectious disease physician; OR = odds ratio.

Discussion

Employment of IDPs could result in savings of 10% in medical expenditure and improve prognosis without influencing LOS. Previous studies have shown the positive effects of infectious disease consultation on the patient's clinical outcome, including increased cure rate and decreased recurrence rate of infection,[17] shortened LOS, and reduced mortality rate.[9,18] The underlying reasons for the improved outcomes were the higher chance of patients receiving evidence-based management through infectious diseases consultation[19] and more appropriate antibiotic treatment for their particular infection.[18] In this study, we revealed better patient outcomes in hospitals employing IDPs compared with those that did not. The improvement in patient outcomes as a result of IDP employment was found in patients aged 18—65 years with a low Charlson score. One explanation might be that adherence to IDPs' recommendations may result in early clinical improvements, reduced in-hospital mortality, shortened LOS,[20] and lowered comorbidity rate.[17] Misuse or overuse of antibiotics could cause antibiotic resistance,[21] further resulting in a high mortality rate, lengthened hospital stay, and increased healthcare costs.[22] The rate of adherence to IDP recommendations was higher in private hospitals than in public hospitals (87% vs. 74%), but was not related to physician tenure.[23] Patients who receive appropriate antibiotic therapy may have better clinical outcomes such as reduced duration of mechanical ventilation, less antibiotic therapy, less intensive care unit (ICU) care, reduced LOS, reduced ICU mortality, and a lower in-hospital mortality rate.[19] Based on previously demonstrated mechanisms and the findings of our study, it is suggested that a more careful diagnostic process, the correct use of antibiotics, and IDP-

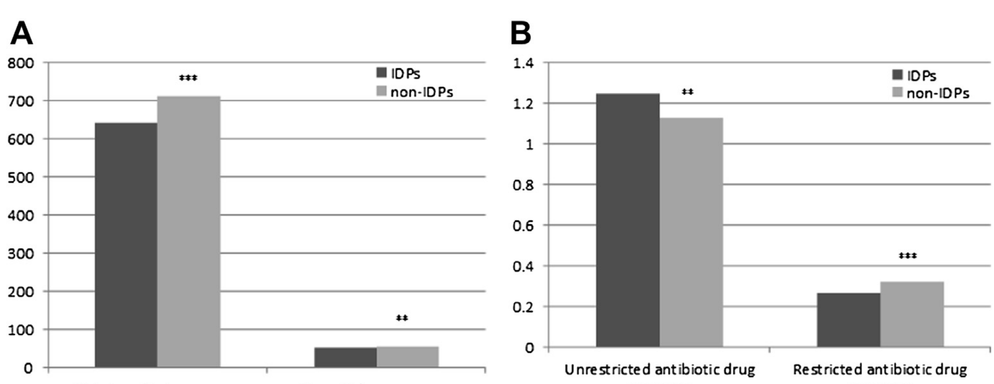

Figure 1. Comparison of medical expenses of patients between the IDPs and non-IDPs groups with a general linear model of multivariable analysis (least-square adjustment was made by patient age, patient sex, hospital length of stay, major diagnosis, Charlson score, treatment outcomes, service volume, physician age, and physician sex). $**p < 0.01$; $***p < 0.001$. IDPs = infectious disease physicians.

assisted systems are likely to improve patient outcome. The Charlson score in the IDP group was higher than that in the non-IDP group. Further stratified analysis showed a statistically significant difference in prognosis between study groups in patients with lower Charlson scores (Charlson score $= 0$, $p < 0.001$; Charlson score $= 1$, $p = 0.06$). The findings suggested that there was no difference in prognosis among complicated cases, where there are additional factors such as therapies other than antibiotic administration and irreversible health conditions. Conversely, the prognosis of patients with less complicated conditions was easily affected by factors such as appropriate antibiotic usage and control.

Medical cost containment has become increasingly important due to limited medical resources and strict regulatory interventions under the global budget payment system in Taiwan. Additional medical expenses due to nosocomial infection had a different financial effect under the previous fee-for-service system and the prospective payment system. Decreased nosocomial infection could improve the quality of patient care and reduce subsequent medical expenses.[24] The prevention of nosocomial infection through infection control could significantly affect medical costs, LOS, and hospital mortality.[6] In addition, prevention of inappropriate antibiotic prescriptions as a result of IDP supervision would decrease medical expenses and avoid potential adverse effects. Therefore, employing IDPs in hospitals could benefit both patients and providers. In addition to demonstrating improved patient prognosis, this study showed that employing IDPs in hospital might help reduce total medical expenses. The hospitals that employed IDPs had 10% lower total medical expenses, 5% lower overall drug expenses, and 18.5% lower restricted antibiotic drug expenses than those hospitals not employing IDPs. The average difference in antibiotic expenses per case was 0.28 USD between the two study groups, while the overall difference in antibiotic expenses between the two groups was 7,415 USD among the 5% samples of inpatient claims. A total difference of 148,305 USD was found between the two groups in the entire 529,660 adult patient population in regional hospitals nationwide. Previous studies have shown that intervention by an antibiotic management team reduced medical costs, with the cost per patient-day reducing from 18 USD to 14 USD in a 575-bed hospital,[25] a 54% reduction in cumulative daily medical cost,[26] a 322,000 USD annual cost savings in a 1200-bed hospital,[27] and a 30.8% decrease in average intravenous antibiotic expenses.[28] Furthermore, the cost of 2,367 USD per quality-adjusted life years gained has been shown to be another important positive effect of an antibiotic management team on economic outcomes.[7] A well-designed antibiotic management team could improve patient care, lower costs, and reduce the number of inappropriate prescriptions.[24] In this study, we were unable to show the effects of appropriate treatment on infectious conditions because efficacy, safety, and reasonable cost must also be considered in the rational use of drugs.[29] Although there was insufficient information on efficacy and safety in this study, we noticed a reverse association of restricted and nonrestricted antibiotic prescriptions between IDPs and non-IDPs. Strategies have been identified to minimize inappropriate treatments, including consulting IDPs, double-checking on prescriptions, and using antibiotic practice guidelines.[30] Furthermore, the appropriate prescription rates of restricted antibiotics and unrestricted antibiotics were shown in the literature to be 88.4% and 58.1%, respectively.[27] Antibiotic expenses were decreased by 18.5% after the introduction of an antibiotic restriction policy regulated by IDPs.[27] An antibiotic restriction policy and consultation provided by IDPs could improve antibiotic use and reduce antibiotic expense.

Employment of IDPs in regional hospitals in Taiwan could be improved in many aspects: (1) the overall physician fees are relatively less attractive to young physicians; (2) many hospitals currently do not employ IDPs; (3) some hospitals employ physicians with other specialties to act as IDPs, which negatively effects the developments of IDPs; and (4) many hospital administrators consider the employment of IDPs as an item of expense, not profit. Using a national database, this study has demonstrated cost savings and quality improvement with the employment of IDPs, which may lead to the re-evaluation of IDPs in the current healthcare system, especially under prospective payment systems. It is suggested to both policymakers and hospital administrators that the employment of IDPs is cost-effective and a positive cost—benefit investment.

This study has six limitations. First, the effect of IDPs was based on the existence in the hospital of a department of infection control. In this study, we did not measure the function or intensity of activities related to antibiotic prescription control. Second, nondifferential misclassification bias might exist as it is difficult to determine efforts and practice patterns from the national health database. If this misclassification exists, the effects shown in this study may be underestimated. Accordingly, the difference in treatment outcomes and medical expenses would be even higher between the two study groups. In other words, the favorable effects of employing IDPs in a hospital would be higher than demonstrated. Third, although the patient profile was corrected to some extent with Charlson scores in this analysis, management systems and policy enforcement were not measured. Therefore, adjustments were not perfect. Fourth, any the incorrect reporting of prognosis and medical expenses may have caused random error in this study. Fifth, although confounding variables will affect outcomes, the confounding effect was randomized into study groups due to the large sample size in this study. We do not know whether any other factors related to employing IDPs among hospitals have affected the outcomes of this study. We assume that the behavior of employing IDPs is independent of medical outcomes. Sixth, the effects of physician fee policy on prescription behavior would have varied among regional hospitals. However, we did not measure those effects.

In conclusion, the potential value of IDPs could be justified based on the results of this study. It is suggested that health policymakers reconsider the employment of IDPs across different levels of hospitals, and managers consider the employment of or investment in IDPs as a cost-effective strategy for improving care quality. Further studies are warranted to validate the findings of this study.

Acknowledgments

This study was partially supported by the National Science Council of Taiwan (98-2410-H-182-011-MY3) and the Healthy Aging Research Center of Chang Gung University. Yi-Chun Lin and Chia-Pang Shih contributed equally to this manuscript.

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