Treatments, outcomes, and costs for AMI patients in Taiwan

Winnie Yip

Department of Public Health,
University of Oxford,
Old Road Campus, Headington,
Oxford OX3 7LF, UK
E-mail: winnie.yip@dphpc.ox.ac.uk

Matthew Polisson

Department of Economics and Nuffield College,
University of Oxford,
Oxford OX1 1NF, UK
E-mail: matthew.polisson@nuffield.ox.ac.uk

Ying-Chun Li

Institute of Health Care Management,
National Sun Yat-Sen University,
70 Lienhai Road, Kaohsiung 80424,
Taiwan, ROC
E-mail: ycli@mail.nsysu.edu.tw

Yiing-Jenq Chou

Institute of Public Health and Department of Public Health,
School of Medicine, National Yang-Ming University,
155 Li-Nong Street, Pei-Tou,
Taipei, Taiwan, ROC
E-mail: yjchou@ym.edu.tw

William Hsiao

Department of Health Policy and Management,
Harvard School of Public Health,
124 Mt. Auburn Street, Suite 410 South,
Cambridge, MA 02138, USA
E-mail: hsiao@hsph.harvard.edu

Abstract: This study examines the treatment-outcome and treatment-cost relationships for Acute Myocardial Infarction (AMI) in Taiwan, where National Health Insurance (NHI) was adopted in 1995. We assessed usage trends in technologically advanced procedural treatments for 31,226 AMI patients from 1997 to 2001, isolated the effects of changes in treatment usage on mortality and medical spending, and compared the values of estimated life-gains to their associated cost increases. Taiwan's experience suggests that by providing comprehensive coverage and by controlling provider prices, NHI was able to improve population-level health by making available technologically advanced procedural treatments while at the same time managing the inflationary pressures associated with these innovations.

Keywords: universal health care; medical technology; AMI; acute myocardial infarction; angioplasty; bypass surgery; Taiwan.

Reference to this paper should be made as follows: Yip, W., Polisson, M., Li, Y-C., Chou, Y-J. and Hsiao, W. (2009) 'Treatments, outcomes, and costs for AMI patients in Taiwan', *Int. J. Healthcare Technology and Management*, Vol. 10, No. 3, pp.169–181.

Biographical notes: Winnie Yip is a Reader in Health Economics at the Department of Public Health, University of Oxford. She received her PhD in Economics from the Massachusetts Institute of Technology. Her major research interests are determinants of health system performances and evaluation of health systems, incentives and provider behaviour, as well as social, economic, and cultural determinants of health and well-being.

Matthew Polisson is a DPhil student in Economics at Nuffield College in the University of Oxford. He holds an MPhil in Economic and Social History from the University of Oxford and an AB in Economics from Harvard University. His primary research interests are in applied microeconometrics and health economics.

Ying-Chun Li is an Assistant Professor at the Institute of Health Care Management at the National Sun Yat-Sen University in Taiwan. His primary research is on topics related to health service research, quality of care, and gerontology. He has recently begun working on a series of studies for elderly persons with multiple chronic diseases.

Yiing-Jenq Chou is a Professor of Public Health at the School of Medicine of National Yang-Ming University. He received his MD from National Yang-Ming University and PhD in Health Policy from Harvard University. His research interests include the economic analysis of impacts of insurance and payment policies on provider and consumer behaviours, and epidemiological evaluations of disaster consequences.

William Hsiao is the KT Li Professor of Economics and Director of the Program in Health Care Financing at the Harvard School of Public Health. His current research focuses on developing an analytical model for diagnosing the causes for the successes or failures of national health systems. He has advised many nations on their health sector reforms, including Vietnam, Colombia, Poland, Taiwan, China, Hong Kong, Sweden, Cyprus, Uganda and South Africa. He was actively engaged in the earlier efforts in the USA in establishing a national health insurance program.

1 Introduction

The debate over universal healthcare generally reveals two competing priorities:

1 to ameliorate the plight of the under-insured, under-privileged, or under-resourced members of society

2 to effectively manage rising medical costs.

While several studies have shown that the uninsured suffer with respect to medical access and health outcomes relative to their insured counterparts, implying that universal healthcare delivers with respect to priority (1), the literature has produced little by way of systematic evidence as to the relationship between universal healthcare and cost inflation, implying that priority (1) may or may not be in conflict with priority (2). By and large, however, this debate has privileged ideology above evidence.

Underlying such a discourse is a common challenge facing health policymakers around the world: how to improve medical access and health outcomes while simultaneously controlling medical spending (Cutler, 2002), a conflict that becomes more pronounced when new medical technologies emerge. Advanced technological treatments have the potential to bring about measurable improvements in health outcomes, but they are also positively associated with increasing medical costs (Cutler and McClellan, 1998; Newhouse, 1992; Weisbrod, 1991). In fact, much of the economics literature in the USA subscribes to the view that technological innovation is one of the primary cost drivers in the healthcare industry (Aaron and Schwartz, 1984; Altman and Blendon, 1977; Cutler and McClellan, 1998; Hay, 2003; Koenig et al., 2003; LaCronique and Sandier, 1981; The Lewin Group, 2002; Newhouse, 1992; Showstack et al., 1982; Weisbrod, 1991; Wilensky, 1990). Are the health improvements associated with new technologies necessarily cost inflationary? And can health systems be structured in such a way as to moderate inflationary pressures without compromising on these health improvements?

We addressed these questions by examining Taiwan's National Health Insurance (NHI) program. Established in March 1995, NHI provides universal and comprehensive insurance to all Taiwanese residents. It covers inpatient hospitalisations, outpatient services, prescription drugs, Chinese medicine, dental care, and home visits. As a single purchaser, the Bureau of NHI (BNHI) has contracts with over 97% of the providers in Taiwan and reimburses them based on a fixed-fee schedule. NHI beneficiaries have complete freedom of choice in providers, with low to moderate cost-sharing.

We analysed patterns in technologically advanced procedural treatment usage, health outcomes, and costs for Taiwanese patients who suffered Acute Myocardial Infarction (AMI). We focused on AMI for several reasons. First, as in many countries, cardiovascular disease is one of the leading causes of death in Taiwan. Second, coronary artery disease patients have benefited from major technological innovations that have proven effective in improving health outcomes, but which are also relatively expensive. Focusing on AMI allows us to investigate the trade-off between improving medical access and health outcomes and managing costs as new technologies are adopted. Third, AMI cases are statistically unambiguous events that allow us to accurately and reliably pinpoint the time of onset. Fourth, given the seriousness of AMI, we may clearly and objectively measure health outcomes as mortality rates following a heart attack.

2 Methods

2.1 Data

The primary data were derived from NHI inpatient claims between 1997 and 2001. Although NHI was established in 1995, data for 1995 and 1996 were unreliable and incomplete, which may have been attributable to errors in recordkeeping and data collection under the new system. The year 2001 provided the last available data at the time this study was conducted. The claims data were similar to American hospital discharge data, or to inpatient claims files for Medicare beneficiaries in the USA. However, as a single insurer, the BNHI compiled records for nearly all recipients of medical care in Taiwan during these years. The claims provided basic demographic information, dates of hospital admission and discharge, diagnosis and procedural codes, and expenditure amounts.

To define a sample of new AMI admissions, we followed methods previously established in the literature (Lo and Lai, 2002). All claims between 1997 and 2001 with a primary diagnosis of AMI (ICD-9-CM code 410) were extracted. To limit the sample to initial AMI admissions, we excluded the following people: patients with ICD-9-CM code 410.02, which indicated subsequent episodes, or follow-up care for previous AMI admissions; patients discharged alive, and not transferred, within three days or less following inpatient admission, assuming that these observations represented miscoded or rule-out rather than true AMI cases; and patients admitted for AMI within one year of the present admission, to ensure that our sample included only new AMI cases.

The inpatient claims were linked to the Department of Health (DoH) death certificate records, which provided the dates and underlying causes of death. The sample subsequently was restricted to patients older than 30 and younger than 85 years of age. Patients of 85 years and older were excluded because death records before 1,911 were incomplete, which may have led to an underestimation of mortality rates for patients of 85 years and older in 1997 if included. Since only a small proportion of the overall sample was less than 30 years of age, we excluded these observations as well. A sensitivity analysis indicated that the results were robust to these age restrictions. The final sample consisted of 31,226 AMI patients between 1997 and 2001, each of whom was assigned to a yearly cohort based on her date of hospital discharge.

2.2 Analysis

Trends in usage for advanced technologies were constructed by estimating the share of patients in each yearly cohort receiving the following treatments: medical management, catheterisation only (ICD-9-CM codes 8853-7, 3722, 3723), Percutaneous Transluminal Coronary Angioplasty (PTCA) (ICD-9-CM codes 3601, 3602 and 3605), and Coronary Artery Bypass Graft surgery (CABG) (ICD-9-CM codes 361 and 3603). We excluded 96 patients (0.3% of the sample) who received *both* PTCA and CABG, a subgroup that may have represented a confounding case-mix. Health outcomes were captured by mortality rates, which were adjusted to the demographic and case-mix distribution for the 1997 cohort. Demographics were captured by age and sex, and case-mix was captured by the Charlson Index (Charlson et al., 1987; Romano et al., 1993). Since there were no direct cost data, we estimated costs using total medical spending per patient, which included expenditures on the initial inpatient hospitalisations as well as any medical spending incurred within one year of those admissions. Expenditures were made under NHI and by patients themselves in the form of co-payments. All figures in this paper are given in 1997 US dollars.

We analysed the extent to which changes in usage shares for advanced technological treatments contributed to changes in mortality rates by decomposing the changes in mortality rates into changes in treatment-specific mortality rates and changes in treatment usage shares. We then analysed the extent to which changes in usage shares for advanced technological treatments contributed to changes in medical spending by decomposing the changes in medical spending into changes in treatment-specific prices and changes in treatment usage shares. Finally, we performed a cost-benefit analysis to compare the changes in the value of life to the changes in treatment expenditure on average. Although there is no general consensus as to the definition of health benefit or reduction, we measured benefit/reduction as the value of life-years gained/lost as a result of changes in mortality rates. To facilitate comparison, we followed closely the methodology applied in previous US studies (Cutler and Huckman, 2003; Cutler and McClellan, 1998; Cutler and McClellan, 2001; Cutler et al., 2001; McClellan and Kessler, 2002; Technological Change in Healthcare Research Network, 2001). Using Taiwanese life tables from the Ministry of Interior (MoI), we first estimated life expectancies conditional upon having survived a heart attack for each year of our five-year period. Given predicted changes in life expectancies, we then estimated changes in expected future life-years discounted to the present at a rate of 3%. We valued these changes at $25,000 per life-year, a value twice the magnitude of Taiwanese per-capita GDP.

3 Results

3.1 Sample characteristics

As shown in Table 1, the average patient was about 65 years of age, and approximately 57.2% of the sample was elderly, classified here as 65 years of age or older. Close to three quarters of the AMI patients were male. Case-mix co-morbidity, captured by the Charlson Index, increased over time. This increase may reflect a real increase in illness severity or upcoding. The share of the population admitted as inpatients for AMI increased between 1997 and 2001 by 2.3% per year on average, 2.5% per year for men and 2.2% per year for women. This increase suggests that, over time, either a larger share of the population suffered AMI, or that a larger share of the population suffering from AMI sought treatment, although the latter is less likely. Because of the severity of AMI, it is unlikely that many patients who suffered a true heart attack were not admitted to a hospital, unless of course the events were fatal.

Female AMI patients tended to be older and sicker than their male counterparts. The share of elderly female patients was approximately 18 percentage points higher than the share of elderly male patients. Female patients also had a higher degree of co-morbid health impairments, partly because they were older. However, the data also showed that heart attack incidence for men was more than 2.7 times that of women. These findings may be due to physiological differences between men and women, where men were more biologically prone to develop heart disease and suffer heart attacks, especially at a younger and healthier stage of life. Alternatively, behavioural differences in treatment-seeking may be attributable to a culture that perceived cardiovascular health risk as a male concern and downplayed the significance of female symptoms, leading to the inpatient hospitalisation of females who were older and in worse health than they would have been otherwise. However, the investigation of these sex differences is beyond the scope of this paper.

Table 1 Characteristics of AMI patients*

Characteristic	*1997*	*1998*	*1999*	*2000*	*2001*
Number of patients	5,631	5,891	6,403	6,565	6,736
Mean age (years)	64.7	64.6	64.6	64.7	64.6
Male	63.2	63.2	63.3	63.2	63.2
Female	68.8	68.7	68.5	68.9	68.7
Female (%)	26.3	26.3	25.5	25.4	26.5
Age ≥ 65 (%)	58.0	57.4	57.3	56.9	56.5
Male	53.2	52.8	53.0	51.7	51.6
Female	71.6	70.0	70.0	72.1	70.1
Charlson Index ≥ 1 (%)†	30.4	33.5	34.9	36.7	36.8
Male, elderly	31.0	34.6	36.4	38.6	38.0
Female, elderly	38.2	40.8	42.9	46.1	47.3
Male, non-elderly	23.9	26.6	27.8	29.2	28.1
Female, non-elderly	37.4	41.5	40.9	40.6	45.1
Charlson Index ≥ 2 (%)	11.0	12.2	12.9	13.1	13.5
Male, elderly	10.4	11.3	12.5	12.3	12.7
Female, elderly	16.7	17.0	19.7	19.9	19.4
Male, non-elderly	7.4	8.7	9.7	9.6	9.6
Female, non-elderly	16.4	20.9	14.1	17.6	21.2
AMI incidence (per 100,000 people)‡	51.6	52.7	56.0	56.2	56.5
Male	74.3	76.0	81.9	82.4	81.9
Female	27.8	28.4	29.1	29.1	30.4

*The AMI sample of 31,226 patients was extracted from NHI claims information for all enrolees between 1997 and 2001.

†For each AMI patient, the Charlson Index is a weighted sum of co-morbid health conditions. Old myocardial infarction, peripheral vascular disease, dementia, chronic pulmonary disease, rheumatologic disease, mild liver disease, and mild to moderate diabetes are each given one point; diabetes with chronic complications, renal disease, and any malignancy (including lymphoma and leukaemia) are each given two points; moderate to severe liver disease is given three points; and metastatic solid tumour is given six points.

‡We estimated incidence using mid-year population counts for people older than 30 and younger than 85 years of age.

3.2 Trends in treatment

As shown in the upper panel of Table 2, treatment patterns changed significantly between 1997 and 2001. There was a major shift away from medical management and towards invasive procedures. In particular, there was a significant increase in the share of patients undergoing PTCA, from 17.8% to 31.7%. While the share of patients undergoing CABG also increased from 1.7% to 2.2%, the share itself remained low.

Table 2 Treatment shares, mortality rates, and medical spending for patients with AMI

	1997	*1998*	*1999*	*2000*	*2001*	*Change**
Share of patients receiving treatment regimen						
Medical management (%)	70.6	68.1	60.6	56.0	54.5	–4.03
Catheterisation only (%)	9.5	8.8	8.9	10.3	11.1	0.40
PTCA (%)	17.8	21.4	28.4	31.3	31.7	3.49
CABG (%)	1.7	1.5	1.7	2.2	2.2	0.12
Average one-year mortality rate for patients receiving treatment regimen†						
Medical management (%)	31.9	31.0	31.9	31.5	31.8	–0.02
Catheterisation only (%)	18.1	17.1	18.1	17.1	17.2	–0.23
PTCA (%)	14.2	13.3	14.2	13.3	13.4	–0.20
CABG (%)	29.7	28.7	29.7	28.8	28.8	–0.22
Overall (%)	27.4	26.0	25.6	24.3	24.3	–0.78
Average medical spending for patients receiving treatment regimen‡						
Medical management ($)	3,223	3,603	3,515	3,829	3,809	4.27%
Catheterisation only ($)	5,111	4,922	5,087	4,694	4,343	–3.99
PTCA ($)	7,053	6,748	6,607	6,958	6,365	–2.53
CABG ($)	23,702	19,748	24,004	20,453	22,455	–1.34
Overall ($)	4,527	4,666	4,977	5,316	5,162	3.33

*Change was annual percentage points for shares/rates and annual percentages for treatment levels.

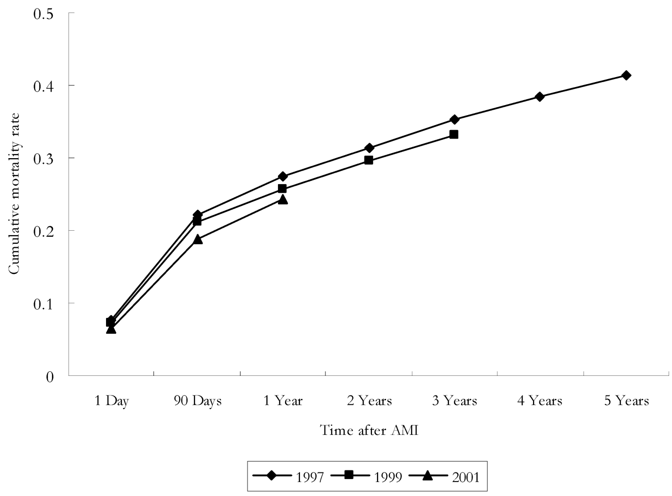
†Mortality rates were adjusted to the 1997 age, sex, and co-morbidity distribution for the AMI population.

‡Medical spending was estimated in 1997 US dollars.

3.3 Trends in outcomes and the treatment–outcome relationship

Adjusted mortality rates were calculated at 1 day, 90 days, and 1–5 years post-AMI for the 1997, 1999 and 2001 cohorts (see Figure 1). As shown in the middle panel of Table 2, conditional upon having survived a heart attack, the cumulative mortality rate one year later was about 27.4% for the 1997 cohort. This figure dropped to 25.6% for the 1999 cohort and 24.3% for the 2001 cohort. These results indicate that overall mortality rates fell by about 0.8 percentage points per year between 1997 and 2001. One-year AMI mortality improved over time across all ages and both sexes fairly equally, yet the reduction was slightly more pronounced for the non-elderly (fell by 0.9 percentage points per year) than for the elderly (fell by 0.7 percentage points per year).

Figure 1 Cumulative mortality rates after AMI*



*Mortality rates were adjusted to the 1997 age, sex, and co-morbidity distribution for the AMI population.

How much of this reduction in mortality can be explained by changes in treatment patterns vs. other factors? As illustrated in the upper and middle panels of Table 2, there were major changes in treatment patterns. Yet the reductions in treatment-specific mortality rates were small relative to the reduction in overall mortality rates. The results from the decomposition (Table 3) showed that around 88% of the total mortality reduction was attributable to increases in the shares of usage for technologically advanced treatments, while 10% was attributable to treatment-specific mortality reductions, which may themselves be related to further technological improvements or better performance by physicians due to accumulated experience. The percentages do not sum to 100 because increases in the shares of usage for technologically advanced treatments and treatment-specific mortality reductions were positively correlated, as evidenced by the positive relationship highlighted in the outcome-volume literature (Luft et al., 1979; Ho, 2000).

Table 3 Decomposition of reductions in mortality rates

Reduction	*Percentage point change*
In mortality	–3.1
Resulting from treatment pattern changes	–2.72 [87.7%]*
Resulting from treatment-specific mortality improvements	–0.31 [10%]

*Bracketed percentages represent shares of the total change. Percentages do not sum to 100 because we ignored the covariance term.

3.4 Trends in costs and the treatment–cost relationship

As shown in the lower panel of Table 2, between 1997 and 2001 real medical spending per AMI patient increased by $635, from $4,527 to $5,162, or 3.3% annually. However, except for basic medical management, real per-capita spending actually decreased.

This suggests that the increase in total per-capita cost was largely driven by the increased share of patients receiving advanced treatments that are more expensive such as PTCA and CABG. How much of the increase in expenditure was explained by increases in the shares of treatment usage vs. changes in the treatment-specific unit prices? The results from the decomposition (Table 4) showed that approximately 31.1% of the increase in expenditure attributable to increases in treatment-specific unit prices, while 105.2% was attributable to changes in shares of usage.

Table 4 Decomposition of increases in medical spending

Increase	*Dollar change*
In medical spending ($)†	635
Resulting from shifts in price ($)	197 [31.1%]*
Resulting from shifts in quantity ($)	668 [105.2%]

*Bracketed percentages represent shares of the total change. Percentages do not sum to 100 because we ignored the covariance term.

†Medical spending was estimated in 1997 US dollars.

3.5 Comparison to the USA

How does Taiwan's experience compare with that of the USA? How did treatment patterns differ? To what relative degree was Taiwan able to achieve health improvements through an increased use of advanced technological procedural treatments while at the same time managing the growth in spending?

Both countries experienced major shifts in treatment towards advanced technologies and away from medical management. However, there was one striking difference. In the USA, the PTCA rate increased from about 1% to about 17%, and the CABG rate increased from about 5% to about 15% for elderly Medicare patients between 1984 and 1994 (Cutler et al., 2001). In Taiwan, the overall increase was sizeable for PTCA, while CABG rates remained relatively low after a slight increase. Although the time periods and demographic characteristics do not allow for a direct comparison, these statistics highlight some of the major differences in usage for advanced technological procedural treatments between the two countries.

We estimated that the reduction in AMI mortality achieved between 1997 and 2001 in Taiwan translated into life-gains worth $31,979, a figure much higher than the cost increase of $635 (see Table 5). If we restrict our sample to the elderly over the same period, the gain was $17,491 of life at a cost increase of only $835, giving a cost-benefit ratio of 0.0477. Between 1984 and 1994, elderly AMI patients in the USA gained $24,397 of life at a cost increase of $7,548, giving a cost-benefit ratio of 0.3094 (Cutler et al., 2001). The American cost-benefit ratio is more than six times that of the Taiwanese ratio.

Table 5 Value of additional life-years and treatment costs for AMI*

Year	*Value of additional life when life-year is worth*			*Medical spending*	
	$10,000/year	*$25,000/year*	*$50,000/year*	*Cost*	*Change*
1997	–	–	–	$4,527	–
2001	$12,792	$31,979	$63,958	$5,162	$635

*Values and spending were estimated in 1997 US dollars.

Table 6 Treatment trends by hospital level

Hospital level	*1997*	*1998*	*1999*	*2000*	*2001*	*Change**
Share of patients admitted at each hospital level						
Medical centre (%)	34.0	33.7	35.9	41.7	42.4	2.10
Regional hospital (%)	34.1	35.7	35.3	39.2	40.3	1.56
Local accredited (%)	14.1	16.0	15.1	9.5	9.7	–1.10
Local non-accredited (%)	17.8	14.5	13.7	9.6	7.5	–2.56
Share of admitted patients receiving PTCA or CABG at each hospital level						
Medical centre (%)	36.8	43.9	52.4	51.7	50.2	3.36
Regional hospital (%)	28.8	30.2	39.3	38.8	39.7	2.72
Local accredited (%)	0.0	0.0	0.0	0.0	0.0	0.00
Local non-accredited (%)	0.0	0.0	0.0	0.0	0.0	0.00
Average one-year mortality rate for patients at each hospital level†						
Medical centre (%)	25.1	23.4	22.6	21.9	22.2	–0.73
Regional hospital (%)	28.0	26.3	25.6	24.8	24.6	–0.84
Local accredited (%)	30.3	29.4	30.3	29.4	29.5	–0.20
Local non-accredited (%)	28.4	27.5	28.4	27.4	27.5	–0.20

*Change was annual percentage points.

†Mortality rates were adjusted to the 1997 age, sex, and co-morbidity distribution for the AMI population.

The comparison between the USA and Taiwan is not ideal. We compared across different time periods, different technologies, and different cultures. However, the magnitude of the difference suggests that at the very least, Taiwan's experience may provide some insight into the trade-off between the utilisation of expensive medical technology and health expenditure inflation.

4 Discussion

Our results suggest that Taiwan was able to achieve substantial AMI mortality reductions while successfully managing cost inflation. During the study period, the reduction in mortality was largely attributable to increased use of advanced technological treatments, while per-unit treatment costs were maintained at low levels. What may be the plausible explanation for these results? Since our data do not pre-date NHI, we cannot infer a direct causal link between the NHI and the observed changes in treatments, mortality rates, and medical spending. However, we can deduce certain logical associations.

First, we hypothesise that the increased use of advanced technological treatments, as well as the associated reductions in mortality rates, were attributable to universal and comprehensive coverage under NHI. The NHI improved access to care and made available otherwise expensive and unaffordable treatments. As shown in Table 6, over five years AMI patients became more likely to be admitted to medical centres and to regional hospitals than to local hospitals. In 1997, the shares of AMI patients treated at medical centres, regional hospitals, and local community hospitals were 34.0%, 34.1%, and 31.9%, respectively. In 2001, those shares were 42.4%, 40.3%, and 17.3%, respectively. These trends are substantial and would not have been possible without the NHI. In Taiwan, medical centres and regional hospitals are higher-level facilities that possess the capacities, including staff and equipment, to perform PTCA and CABG. Medical centres and regional hospitals also have larger patient volumes or heavier teaching responsibilities, two factors which generally contribute to better patient outcomes. As shown in the lower panel of Table 6, not only were mortality rates at medical centres and regional hospitals lower (15.9% lower on average across five years), but also the reduction over time was greater for these facilities. Mortality rates following a heart attack fell by approximately 0.7 and 0.8 percentage points per year for medical centres and regional hospitals, respectively, while mortality rates decreased by about 0.2 percentage points per year for the local community hospitals.

Second, we hypothesise that the methods of payment and the organisation of hospitals and physicians may have allowed Taiwan to manage expenditure growth for AMI cases, despite the rapid increase in use of technologically advanced treatments. As a single purchaser, Taiwan's NHI pays providers according to a fixed-fee schedule. When NHI was established in 1995, the effectiveness of PTCA, in terms of rates of restenosis and mortality, had improved considerably since it was first introduced in the late 1980s (Williams et al., 2000). To create incentives for providers to select PTCA over the more expensive CABG, the BNHI set a fee schedule that compensated PTCA procedures relatively more generously than CABG procedures. To illustrate, in 1996, the fee for a two-vessel PTCA was $1,715, while that for CABG was only $915. Unlike the USA, Taiwan's NHI pays hospitals rather than physicians. All physicians are employed as hospital staff, and non-staff physicians do not have admitting privileges. Hospitals pass on financial incentives to their physician staff by sharing a fixed percentage of the procedure-specific fees they receive with their physicians. Given that CABG is more difficult and riskier than PTCA, relative price differences provide a major incentive for PTCA above CABG. In addition, as a single payer with one payment method and one payment rate, the NHI can also effectively control system-level cost by avoiding cost-shifting, a problem that often plagues systems with multiple payers, as in the USA.

There are several limitations for these inferences and conclusions. First, our study focuses on the experience of AMI patients, and it does not address the broader question of whether the increased usage of advanced technological procedures is necessarily cost-increasing in general. To test that, a study would need to examine treatment, outcome, and cost for a comprehensive group of diseases. Second, Taiwan's NHI did not reimburse PTCA with more than two stents until after 2001, which means we have underestimated the actual use of PTCA. Third, in addition to differences in payment incentives as discussed above, the relatively low rates of CABG may be attributable to other factors, which we cannot empirically isolate. For example, by the time Taiwan adopted PTCA and CABG, exogenous technological changes and accumulated knowledge had made PTCA a more attractive option than when it was adopted in the USA in the 1980s (Williams et al., 2000). Some researchers in Taiwan have suggested that the relatively low ratio of cardiac surgeons to cardiologists places further constraints on the expansion of CABG. What explains the relatively low supply of cardiac surgeons is, however, a separate question.

Despite these limitations, the major change in AMI patients' admission to higher-level facilities, the rapid increase in the use of PTCA, and the large magnitude of difference in the use of CABG between the USA and Taiwan suggest that comprehensive insurance coverage and the use of pricing incentives by the NHI are key contributors to the observed trends. Our results strongly suggest that the ways in which health systems are structured can be important determinants in whether a system can strike a balance between improving access and population health while effectively managing cost.

Acknowledgements

The authors gratefully acknowledge the joint financial support of the BNHI and the National Health Research Institute (NHRI) in Taiwan. We also thank the BNHI for providing the data.

References

Aaron, H.J. and Schwartz, W.B. (1984) *The Painful Prescription: Rationing Hospital Care*, Brookings Institution, Washington, DC.

Altman, S.H. and Blendon, R. (Eds.) (1977) *Medical Technology: The Culprit Behind Health Care Costs?*, Government Printing Office, Washington, DC.

Charlson, M.E., Pompei, P., Ales, K.L. and MacKenzie, C.R. (1987) 'A new method of classifying prognostic comorbidity in longitudinal studies: development and validation', *Journal of Chronic Diseases*, Vol. 40, pp.373–383.

Cutler, D.M. (2002) 'Equality, efficiency, and market fundamentals: the dynamics of international medical-care reform', *Journal of Economic Literature*, Vol. 40, pp.881–906.

Cutler, D.M. and Huckman, R.S. (2003) 'Technological development and medical productivity: the diffusion of angioplasty in New York state', *Journal of Health Economics*, Vol. 22, pp.187–217.

Cutler, D.M. and McClellan, M. (2001) 'Is technology change in medicine worth it?', *Health Affairs*, Vol. 20, pp.11–30.

Cutler, D.M. and McClellan, M.B. (1998) 'What is technological change?', in Wise, D.A. (Ed.): *Inquiries in the economics of aging*, University of Chicago Press, Chicago.

Cutler, D.M., McClellan, M., Newhouse, J.P. and Remler, D. (2001) 'Pricing heart attack treatments', in Cutler, D.M. and Berndt, E.R. (Eds.): *Medical Care Output and Productivity*, University of Chicago Press, Chicago.

Hay, J.W. (2003) 'Hospital cost drivers: an evaluation of 1998–2001 state-level data', *American Journal of Managed Care*, Vol. 9, pp.SP13–SP24.

Ho, V. (2000) 'Evolution of the volume-outcome relation for hospitals performing coronary angioplasty', *Circulation*, Vol. 101, pp.1806–1811.

Koenig, L, Siegel, J.M., Dobson, A., Hearle, K., Ho, S. and Rudowitz, R. (2003) 'Drivers of healthcare expenditures associated with physician services', *American Journal of Managed Care*, Vol. 9, pp.SP34–SP42.

LaCronique, J.F. and Sandier, S. (1981) 'Technological innovation: cause or effect of increasing health expenditures', in Altenstetter, C. (Ed.): *Innovation in Health Policy and Service Delivery: A Cross-National Perspective*, Oelgeschlaher, Gunn and Hain, Cambridge, MA.

Lo, J.C. and Lai, M. (2002) 'Technological change in heart attack care in Taiwan', in McClellan, M.B. and Kessler, D.P. (Eds.): *Technological Change in Health Care: A Global Analysis of Heart Attack*, University of Michigan Press, Ann Arbor.

The Lewin Group (2002) 'Study of healthcare outpatient cost drivers', *What's Behind the Rise: A Comprehensive Analysis Of Healthcare Costs*, Blue Cross and Blue Shield Association, Chicago.

Luft, H.S., Bunker, J.O. and Enthoven, A.C. (1979) 'Should operations be regionalized? The empirical relation between surgical volume and mortality', *New England Journal of Medicine*, Vol. 301, pp.1364–1369.

McClellan, M.B. and Kessler, D.P. (Eds.): *Technological Change in Health Care: A Global Analysis of Heart Attack*, University of Michigan Press, Ann Arbor.

Newhouse, J.P. (1992) 'Medical care costs: How much welfare loss?', *Journal of Economic Perspectives*, Vol. 6, pp.3–21.

Romano, P.S., Roos, L.L. and Jollis, J.G. (1993) 'Adapting a clinical comorbidity index for use with ICD-9-CM administrative data: differing perspectives', *Journal of Clinical Epidemiology*, Vol. 46, pp.1075–1079.

Showstack, J.A., Shroeder, S.A. and Matsumoto, M.F. (1982) 'Changes in the use of medical technologies, 1972–1977: a study of ten inpatient diagnoses', *New England Journal of Medicine*, Vol. 306, pp.706–712.

Technological Change in Health Care (TECH) Research Network. (2001) 'Technological change around the world: evidence from heart attack care', *Health Affairs*, Vol. 20, pp.25–42.

Weisbrod, B.A. (1991) 'The health care quadrilemma: an essay on technological change, insurance, quality of care, and cost containment', *Journal of Economic Literature*, Vol. 29, pp.523–552.

Wilensky, G.R. (1990) 'Technology as culprit and benefactor', *Quarterly Review of Economics and Business*, Vol. 30, pp.45–53.

Williams, D.O., Holubkov, R., Yeh, W., Bourassa, M.G., Al-Bassam, M., Block, P.C., Coady, P., Cohen, H., Cowley, M., Dorros, G., Faxon, D., Holmes, D.R., Jacobs, A., Kelsey, S.F., King, S.B., Myler, R., Slater, J., Stanek, V., Vlachos, H.A. and Detre, K.M. (2000) 'Percutaneous coronary intervention in the current era compared with 1985–86: the national heart, lung, and blood institute registries', *Circulation*, Vol. 102, pp.2945–2951.