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Impact of performance grading on annual numbers of acute myocardial infarction-associated emergency department visits in Taiwan

Results of segmented regression analysis

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Abstract

To reduce patient boarding time at the emergency department (ED) and to improve the overall quality of the emergent care system in Taiwan, the Minister of Health and Welfare of Taiwan (MOHW) piloted the Grading Responsible Hospitals for Acute Care (GRHAC) audit program in 2007–2009.

The aim of the study was to evaluate the impact of the GRHAC audit program on the identification and management of acute myocardial infarction (AMI)-associated ED visits by describing and comparing the incidence of AMI-associated ED visits before (2003–2007), during (2007–2009), and after (2009–2012) the initial audit program implementation.

Using aggregated data from the MOHW of Taiwan, we estimated the annual incidence of AMI-associated ED visits by Poisson regression models. We used segmented regression techniques to evaluate differences in the annual rates and in the year-to-year changes in AMI-associated ED visits between 2003 and 2012. Medical comorbidities such as diabetes mellitus, hyperlipidemia, and hypertensive disease were considered as potential confounders.

Overall, the number of AMI-associated patient visits increased from 8130 visits in 2003 to 12,695 visits in 2012 (P-value for trend $<$ 0.001), corresponding to an average annual growth rate of 5.3% (95%confidence interval [CI]: 0.5–10%). Although age was a major risk factor for AMI-associated ED visits, the statistical association was observed in middle-to-old (aged 40–64; P-value $<$ 0.001) and older aged individuals (aged ≥65; P-value <0.001). As compared to 2003–2007, AMI-associated ED visits increased slightly during the intervention roll-in period (2007–2009, slope = 394.5, P-value = 0.117) followed by a dramatic uptake in the early post-intervention period (2010–2012, slope = 1037, P-value = 0.083).

There was evidence suggesting for a significant intervention effect of the GRHAC program on identifying critically ill patients with AMI-associated diagnosis at the ED. As the program evaluation is still ongoing, we expect to observe a sustained program effect on hospitals' capacity for timely and correctly diagnosing and managing patients presenting with AMI-associated symptoms or signs at the ED.

Abbreviations: AMI = acute myocardial infarction, CAD = coronary artery diseases, CI = confidence interval, DM = diabetes mellitus, ECG = electrocardiography, ED = emergency department, EMS = emergency medical systems, GRHAC = grading responsible hospitals for acute care, ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification, LL = lower level, MOHW = Ministry of Health and Welfare, PCI = percutaneous coronary intervention, UL = upper level.

Keywords: acute myocardial infarction, ED crowding, policy intervention, program evaluation, segmented regression analysis

Editor: Chun Gao.

Funding: This study was partly supported by a grant from Chang Gung Memorial Hospital at Linkou, Taiwan (CMRPG3E0911) and the Ministry of Science and Technology, Taiwan (MOST 105-2325-B-002-027).

The authors have no funding and conflicts of interest to disclose.

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Medicine (2016) 95:42(e4937)

Received: 22 March 2016 / Received in final form: 25 July 2016 / Accepted: 30 August 2016

http://dx.doi.org/10.1097/MD.0000000000004937

1. Introduction

In recent years, the quality of medical care for major heart disease has become an issue of great concern in developed countries.[1] In Taiwan, to improve the quality of critical emergent service within the hospital system, the Ministry of Health and Welfare (MOHW) has emphasized the importance of capacity building at the hospital level for disaster monitoring and emergent responses by initiating the Grading Responsible Hospitals for Acute Care (GRHAC) audit program in 2007–2009.[2] The pilot GRHAC audit program involved (professional) education, training, equipment upgrades, and space renovation beginning in 2007, followed by official onsite auditing and level grading of emergency department (ED) performance for the first time in the second half of 2009. After the pilot period, the continuing GRHAC audit program has re-assessed and re-issued performance grades every other year.

The main objective of the GRHAC audit program is to periodically assess, monitor, and evaluate the performance and the capacity of individual hospital EDs[3,4] in response to emergent needs for medical care. The major evaluation items of the audit program include disposable medical resources; management; efficiency, as measured by the percentage of delayed treatments after the initial diagnosis (or assessment) of patients in the observation room; and patient disposition, as quantified by a reasonable (or acceptable) transfer or referral percentage. Issue can then be addressed by developing a "manageable capacity plan" for each hospital within 1 of the 6 regional networks in order to provide critically ill patients with timely disposition to an appropriate, "responsible" hospital (usually a tertiary medical center) of the same region.[2]

As cardiovascular diseases have been among the major causes of death in many developed countries, including Taiwan,[5,6] acute myocardial infarction (AMI) has been one of the index diagnoses for grading the critical care performance of hospital EDs by the GRHAC audit program.[2] As per the audit program, for the correct and timely identification and management of AMI patients upon their hospital arrival, a majority of confirmed or suspected AMI cases need to receive standard 12-lead electrocardiography (ECG), cardiac catheterization, and routine blood examinations within a pre-designated time interval. There are 6 orientations were proposed to grade responsible hospitals for disposition of AMI patients. These orientations included: (1) request disposal protocol for AMI patients, (2) provide emergency consultation mechanism with division of cardiology, (3) provide emergency consultation mechanism with division of cardiovascular surgery, (4) to facilitate patient transport to the catheterization laboratory with a portable multifunctional monitor, and provide an oxygen device at the bed site immediately when the process of primary percutaneous coronary intervention (PCI) was executed, (5) provide good medical care for AMI patients to meet quality requirements, and (6) the technicians in the catheterization laboratory maintain basic PCI equipment in sterile status when the process of primary PCI was executed at all times.

To adequately evaluate the audit program impact island-wide, an underlying temporal trend in the incidence of coronary artery diseases over the past decade needs to be taken into account, as was suggested by several studies conducted in Western developed countries.[7,8] However, there are few studies to investigate the secular trend in the incidence of AMI or the in-hospital mortality rate in the general population of Taiwan. According to a recently-published study,[9] the incidence rates of AMI increased from 30 in 1997 to 42 in 2011 (per 100,000 persons); the in-hospital mortality rates after AMI decreased from 9.1% in 1997 to 6.5% in 2011.

Meanwhile, lifestyle factors and dietary factors may have affected the incidence of cardiovascular diseases during the same calendar period.[10–12] Specifically, obesity and overweight, major cardiovascular risk factors have become increasingly common in Taiwanese adults in recent decades.[13] High amounts of fat intake and a sedentary lifestyle have also been shown to increase the risk of diabetes mellitus (DM), hyperlipidemia, and hypertension,[14–18] all of which further predispose individuals to coronary artery disease (CAD).

In the current study, we attempted to determine the immediate impact of the GRHAC audit program on the annual rates of AMI-related ED visits by comparing the rate before (2003–2006) and after (2010–2012) the implementation of the GRHAC audit program in 2007–2009. We used de-identified insurance claim data while properly accounting for natural trends that were associated with population aging and lifestyle changes.

2. Methods and materials

2.1. Data source and study population

The Health Promotion Administration of the MOHW in Taiwan has maintained electronic databases of all ED visits that are indexed by the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) Codes from 2003 to 2012.[19] The publicly available datasets can be downloaded in the aggregated format of contingency tables, consisting of numbers of ED visits by sex, age (in 1-year intervals), and ICD-9-CM codes for each year.

All adult patients aged 20 or older who were diagnosed as having AMI (ICD-9-CM code group: 410) at the ED in 2003–2012 were included in the following analysis. Although AMI was mainly a diagnosis for middle-aged or old adults (aged ≥40 years), we retained ED visits by younger adults (aged 20–39) as a comparison group in the following analysis. The current study's analytic plan was reviewed and approved by the Institutional Review Board of Chang Gung Memorial Hospital at Linkou.

2.2. Outcome and derived variables

The outcome variable, denoted as Y_i, was the number of AMI-associated patient visits to the ED for the 3 calendar periods ($i = 1–3$)—2003–2006, 2007–2009, and 2010–2012—each representing years before, during, or after the GRHAC implementation. Visit rates were defined as follows:

$$\text{Visit rate per year per 100,000 persons} = \frac{\text{The number of patient visits to the ED per year}}{\text{Mid-year population per year}} \times 100{,}000$$

The inversion formula for practice outcome was calculated as follows:

$$\text{Number of patient visits to the ED per year} = \frac{\text{Visit rate per year per 100,000 persons}}{100{,}000} \times \text{Mid-year population per year}$$

Several covariates related to the outcome variable were considered as potential confounders, including male sex (proportion of men in the mid-year population covered by the National Health Insurance program), age (in 3 groups, 20–39, 40–64, and ≥65 years) and medical co-morbidities (diabetes mellitus [ICD-9-CM code:250],[20,21] hyperlipidemia [ICD-9-CM code:2720 and 2721],[22] and hypertensive disease [ICD-9-CM code:401 to 405].[22]

2.3. Statistical analysis

As the aggregated data were count data in the format of contingency tables, we applied Poisson regression models on the annual AMI-associated ED visits while assuming a stable at-risk population size each year between 2007 and 2012. By dividing the number of relevant ED visits occurred in a given year, we compared changes in the annual incidence of AMI-associated ED visits before, during, and after the program implementation. In addition to graphically displaying the number of AMI-associated ED visits for the overall population and by age group, descriptive analysis of AMI-associated ED visits was performed by sex, age group, and the presence of medical co-morbidities for the 3 observation periods separately.

The proportion of AMI-associated patient visits in which there was a concurrent diagnosis of DM, hyperlipidemia, or hypertension was calculated for each calendar period separately. Chi-square tests of significance were used to examine differences in the distribution of sex, age, and each of the major cardiovascular comorbidities for the 3 observation periods, separately, assuming that each patient visit had only 1 medical comorbidity during the specific study period.

Next, we used segmented regression analysis of interrupted time series[23–25] to estimate the association between numbers of AMI-associated ED visits per year, time (period), intervention, and time (period) after intervention using multiple linear regression models. Level and slope are 2 parameters that define the intercept and slope for each successive segment of time series, respectively. The level parameter is the expected or mean number of patient visits at the time interval, and the slope parameter quantifies the change in the number of patient visits over a single-unit time period (per year). A disjoint, interrupted intervention effect constitutes the step-change (change in the intercepts) between any 2 consecutive periods of the outcome after the intervention. Before-and-after changes in the number of patient visits were estimated by testing differences between the slopes of post- and pre-intervention time periods. Specifically, estimators of segmented regression include: *time* (calendar years before intervention), *intervention* (the index year [s]), and *time after intervention* (calendar years after intervention). The multivariable, linear regression model with 1 change-point is shown as follows:

$$Y = \beta_0 + \beta_1\text{time} + \beta_2\text{intervention} + \beta_3\text{time after intervention} + \beta_4\text{male sex} + \beta_5\text{age} + \beta_6\text{Diabetes melltius} + \beta_7\text{Hyperlipidemia} + \beta_8\text{Hypertensive disease} + \text{Random error}$$

To better quantify for the early impact of the GHRAC audit program, we additionally compared model-predicted patient visits with extrapolated numbers from 2 hypothetical scenarios. In the first "aging only" scenario in which there was no audit program implementation, we obtained numbers of ED visits for the years 2007–2012 based on a fitted, linear trend for the pre-intervention period (2003–2006, Scenario A). Alternatively, in the second "steady state" scenario in which we assumed no significant secular changes since 2006, we obtained a constant number of patient visits for the roll-in and the post-intervention years (Scenario B). All analysis was performed at a 2-sided significance level of 0.05 using *R* (version 3.1.0).[26]

Table 2

Parameter estimates, standard errors, and *P*-values from full segmented regression model predicting annual AMI patient visit numbers in the ED.

Segmented regression model	Coefficient	95% CI (LL, UL) Patient-visits	*P*
Intercept (Baseline level)	873.9	(463.8, 1646.6)	<0.001*
Baseline slope	1.0	(1.0, 1.0)	0.001*
Level change	0.9	(0.9, 1.0)	<0.001*
Slope change	1.1	(1.1, 1.1)	<0.001*
Male vs female	0.3	(0.1, 0.7)	0.003*
Age			
Level change for adults aged 40–64 years	10.5	(10.0, 11.1)	<0.001*
Level change for adults aged ≥65 years	17.6	(13.9, 22.3)	<0.001*
Diabetes mellitus	1.0	(1.0, 1.0)	0.004*
Hyperlipidemia	1.0	(1.0, 1.0)	0.256
Hypertensive disease	1.0	(1.0, 1.0)	<0.001*

AMI = acute myocardial infarction, CI = confidence interval, ED = emergency department, LL = lower level, MOHW = Ministry of Health and Welfare, UL = upper level.
* Significant at the 0.05 level.

Table 1

Case numbers of ED patient visits.

Characteristics	Overall Total (%) N=93251	Intervention phases: Pre-(2003–2006) Total (%) N=31790	Roll-in (2007–2009) Total (%) N=26723	Post-(2010–2012) Total (%) N=34738	*P*
Gender					
Male	66491 (71.3)	22393 (70.4)	19148 (71.7)	24950 (71.8)	0.0001
Female	26760 (28.7)	9397 (29.6)	7575 (28.3)	9788 (28.2)	
Age					
20–39	3979 (4.3)	1502 (4.7)	1123 (4.2)	1354 (3.9)	<0.0001
40–64	38577 (41.4)	13132 (41.3)	10854 (40.6)	14591 (42.0)	
≥65	50695 (54.3)	17156 (54.0)	14746 (55.2)	18793 (54.1)	

ED = emergency department.

Table 3

Results of the comparison of predicted AMI-associated patient visits to the ED to extrapolated estimates obtained from hypothetical scenarios (A and B) during and after the intervention period.

	Intervention roll-in period								
	2007			2008			2009		
Patient visits	Visits	Difference	95%CI	Visits	Difference	95%CI	Visits	Difference	95%CI
Observed	8471	–	–	8992	–	–	9260	–	–
Predicted	8315	–	–	8913	–	–	9616	–	–
Scenario A	8108 (3%)*	207	165–249	8172 (9%)	741	690–792	8236 (17%)	1380	1318–1441
Scenario B	8044 (3%)	271	249–294	8044 (11%)	869	847–892	8044 (20%)	1572	1550–1595

	Postintervention period								
	2010			2011			2012		
Patient visits	Visits	Difference	95%CI	Visits	Difference	95%CI	Visits	Difference	95%CI
Observed	10621	–	–	11422	–	–	12695	–	–
Predicted	10626	–	–	11441	–	–	12550	–	–
Scenario A	8301 (28%)	2325	2254–2397	8365 (37%)	3076	2994–3159	8429 (49%)	4121	4027–4215
Scenario B	8044 (32%)	2582	2560–2605	8044 (42%)	3397	3375–3420	8044 (56%)	4506	4484–4529

AMI = acute myocardial infarction, CI = confidence interval, ED = emergency department.
* Percentage difference = 100% × ([predicted − extrapolated]/predicted). All *P*-values <0.0001.

3. Results

In 2003–2012, there were 93,251 AMI-associated ED visits made by adults aged 20 or older, >70% of which were men (71.3%, Table 1). Young (aged 20–39 years) and middle-aged patients (aged 40–64 years) contributed 4.3% (N=3979) and 41.4% (N=38,577) of these AMI-associated ED visits whereas the elderly (age ≥ 65 years) was the predominant source population (N=50,695, 54.3%, Table 1). A predominance of male, elderly patients was consistently observed across the 3 calendar periods (Table 1).

Overall, AMI-associated ED patient-visits increased from 8130 in 2003 to 12,695 in 2012, representing a total increase of 4565 visits during the 9-year observation period. Correspondingly, the mean annual increment was 507 visits (95% CI: 47–967), with an average annual growth rate of 5.3% (95% CI: 0.5–10%). The mean annual growth rate was 5.4% (95% CI: 0.2–10.7%) and 4.9% (95% CI: 0.1–9.6%) for male and female visits during the 9-year observation period, respectively. In 3 age groups, 20 to 39, 40 to 64, and ≥65 years, the mean annual increase rate in visits was 3.5% (95% CI: –1.3–8.4%), 5.5% (95% CI: –0.4–11.5%), and 5.2% (95% CI: 0.7–9.7%), respectively.

As shown in Table 2, there was significant change point for the intercepts (the level parameters), and there also was a statistically significant overall trend in the number of patient visits (*P*-value = 0.001). In particular, the increase in AMI-associated ED visits was of significance for both middle-aged and older adults (both *P*-values for level change <0.0001).

Percent differences between model-estimated ED visits and those obtained from Scenario A ranged from 3% in 2007 to 17% in 2009, whereas those differences between predicted visits and hypothetical visits in Scenario B ranged from 3% to 20% for the roll-in period. Results of statistical comparison between the model-based estimates and either extrapolated patient visits showed a slight yet significant positive difference in AMI-associated patient visits for each year during the roll-in period (all *P*-values <0.001, Table 3). The suggested audit program impact,

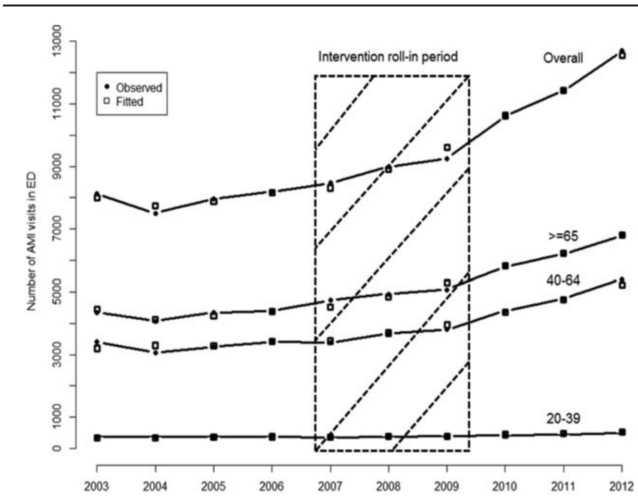

Figure 1. Number of AMI-associated patient visits to the ED between 2003 and 2012. AMI = acute myocardial infarction, ED = emergency department.

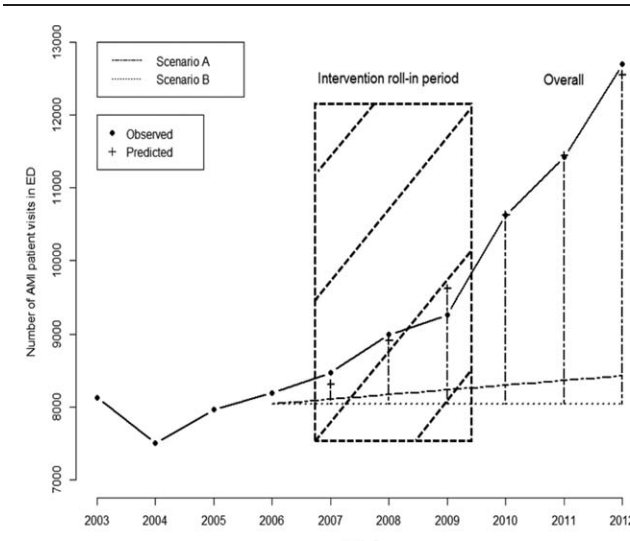

Figure 2. Intervention effects on the primary outcome measure using the segmented regression model.

as might be reflected from the percent changes comparing predicted to hypothetical numbers, increased dramatically, up to 49% (relative to Scenario A) or 56% (relative to Scenario B) during the early postintervention periods (Table 3).

Figure 1 shows the fitted numbers of patient visits for AMI by age groups across the 3 calendar periods. Both the observed and the model-based estimates are shown for comparison. The increase in the overall AMI-associated ED visits over the 9-year period mainly resulted from the increases in the middle-aged and older age groups, whose upward trends appeared parallel to each other during the observation period (Fig. 1). Results of the comparison of model-based predicted outcome with Scenario A (representing a natural increase presumably due to ageing) and with Scenario B (representing no change since 2006) have also been shown (Fig. 2).

4. Discussion

We implemented a secondary analysis to evaluate the temporal changes in AMI-associated patient visits to the ED and the audit program effect of GRHAC. As the pilot audit program of GRHAC to implement, this audit program effect might obvious if the temporal changes in AMI-associated patient visits to the ED concepts and pilot audit program-related concepts were used to explicitly state the important conceptual relationships using segmented regression of interrupted time series. In this study, we compared changes in the expected level and the growth rate of AMI-associated patient visits using insurance claim data. We also quantified potential intervention effects based on comparisons between model-predicted and extrapolated numbers derived from the observed trends.

Although an immediate increase in AMI-associated ED visits was observed in the first post-intervention year (2007), it is unlikely that the AMI incidence rate could have dramatically increased within such a short time frame. The phenomenon can be explained by more aggressive disposition decisions made by the pre-hospital emergency medicine service (EMS) teams, a higher likelihood for ED physicians to make AMI-associated diagnoses (over-diagnosis or surveillance bias), as well as an overall increased awareness of AMI-relevant symptoms and signs by the general population, including at-risk patients and their family members.

Since the 1990s, the Chin-Shan Cardiovascular Study,[27] a longitudinal cohort study located in a small fishing village in Northern Taiwan, has continually monitored the general health of the village people for >2 decades. As the Chin-Shan Study has followed a relatively old cohort that is continually aging, reported rates of AMI may not be directly applicable to the general population across the island. In comparison, information obtained from the insurance claim data collected across cities and counties throughout the island is population-representative and can better inform policy makers and other stakeholders of temporal changes in the utilization of healthcare resources.

Despite the implementation of interventions designed to provide critically ill patients with timely disposition to an appropriate, responsible hospital, there has been persistent growth of AMI patient visits to the ED over time. Thus, it is important to evaluate the effectiveness and outcomes of this audit program. In this study, we noted that ED visits by older adults (≥ 65 years) might serve as a sentinel event for substantial growth in AMI-associated patient visits to the ED. Therefore, we suggest further prospective investigation of older patients after their discharge from the ED. This prospectively collected information may provide valuable insights on identifying clinical, psychosocial, and EMS risk factors for repeated ED attendance by the elderly population. Such studies may also generate a base of evidence for evaluating the success of GRHAC in meeting the acute healthcare needs of the critical population.

National audit programs to investigate associated quality improvement in the healthcare setting have been reported else where. For example, in Croatia, the National Interventional Cardiology Program has established to monitor integrated diagnosis and therapy of care with AMI-associated patients since mid-2005. This program aimed at more effective life saving and disability reduction than in case of traditional pharmacology-based strategy.[28]

Moreover, the Improving Cardiovascular Outcomes in Nova Scotia (ICONS) project used a prospective cohort study which involved all 34,060 consecutive adult patients hospitalized with AMI, unstable angina (UA) or congestive heart failure (CHF) during October 1997–March 2002 in Nova Scotia. This project aimed at enhanced care and improved outcomes across an entire healthcare system. Interventions of this project combined serial audits, such as feedbacks of practices and outcomes. Although there were no changes in 1-year mortality for any disease, this project has had an observable impact on rates of re-hospitalization, which declined significantly for all diseases though the course of ICONS.[29]

There are limitations in this study. First, covariates for adjustment were limited in number and in detailed categories due to the lack of individual level data. Hence, there is a risk of unmeasured and uncontrolled confounding in the current analysis. Second, there were a relatively small number of time points available for data analysis (2003–2012). Specifically, the relatively short pre-intervention period (2003–2006) may have limited the statistical power for the segmented regression analysis in detecting minimal changes in the level or slope parameters.[30] In additional, in studies where there is also variability among the AMI-associated exposure of interest, the analysis may be confounded since AMI rates increased over the entire study period, not just after implementation of the audit program.

Moreover, some important quality indicators, such as length of stay, boarding time, number of primary PCI, were not available to allow for comprehensive quantification of the continuous improvement of quality of care for AMI patients at ED during the same observation period. There were no other measurements to evaluate changes in providers' clinical timely awareness of AMI symptoms or signs either. Regardless, it was the goal of the Program that, by implementing such auditing activities, each participating hospital (ED) would strive to achieve or maintain its clinical performance grade by continual training and educating their healthcare providers, including their support for the EMT team at the local Fire Department.

In conclusion, through segmented regression analysis of AMI-associated ED visits at successive segments in 2003–2012, we found evidence indicative of a substantial increase in AMI-associated ED visits in participating hospitals over a decade. In addition to secular trends in population ageing and lifestyle changes, these changes may suggest a significant, early-phase (2007–2012) effect of a policy intervention program at the hospital level.

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