Coronary Angiography Utilization and Costs for Coronary Artery Bypass Graft Surgery Patients in Turkey

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ABSTRACT

Introduction: To assess excess use of coronary angiography prior to coronary artery bypass graft surgery and its association with mortality, health care costs, and hospital quality in Turkey.

Methods: Using Turkish National Health Insurance Data (2009–2011) that included patients who underwent cardiac surgery, coronary angiography utilization was identified.

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Propensity score matching was used to compare survival rates and annual health care costs of patients in a coronary angiography excess-use group (>1 angiogram) and in a standard-therapy group (1 angiogram). The empirical Bayesian approach was used to combine mortality and hospital volume for quality index. The relationship between hospital quality and excess use of coronary angiography was assessed using Chi-squared tests.

Results: Out of 20,126 patients identified, 7.27% of patients underwent excessive coronary angiography procedures (excess-use group), with an average annual cost at 9.7% higher than those who had a single angiography (standard-therapy group; $P < 0.01$). Operational mortality associated with excessive use was significantly higher as well (7.4% versus 5.4%, $P < 0.02$). There exists variation in the use of coronary angiography across cities and hospitals. Patients who underwent cardiac surgery in high-quality hospitals were less likely to have excessive angiography use than those in low-quality hospitals (7.0% versus 9.5%, $P < 0.01$).

Conclusion: In Turkey, excess use of coronary angiography prior to coronary artery bypass graft surgery is associated with higher

operational mortality, higher expenditures, and lower hospital quality.

Keywords: Angiography; Coronary artery bypass graft surgery; Coronary artery disease; Health care costs; Hospital quality; Turkey

INTRODUCTION

Coronary artery bypass graft (CABG) surgery is one of the most common surgical procedures performed to relieve angina symptoms in patients with coronary artery disease [1, 2]. The surgery improves the quality of life and survival rates of patients with coronary artery disease [3–5].

Coronary angiography is considered the standard procedure for CABG assessment [6]. Every year, millions of patients get an angiogram, wherein a long, thin, flexible tube called a catheter is inserted in the arm or groin, and threaded to the heart to check for blocked arteries that may lead to a heart attack. Dye is injected through the tube to make blockages visible on X-rays [7]. Although angiographies are effective in select populations, the overall appropriateness of their use is questioned [8–10]. The test carries a small (<1%), but serious, risk of causing a stroke or heart attack, and also entails radiation exposure [11].

The troubling association between the increased number of CABG surgeries and high frequency of costly angiograms to check for heart disease has caused payers to request studies to outline the benefits, risks, and outcomes of these procedures. The cost of these procedures will be major contributors to increased health care spending [12]. Prior studies have indicated that excess use of and increased costs associated with these procedures are related to variation in the quality of care [13].

This study aimed to demonstrate the variation in the use of coronary angiography for patients who underwent CABG surgery in Turkey using nationwide, real-world data. The difference in mortality rates and annual health care costs associated with coronary angiography overuse was calculated. The correlation between the number of angiographies and hospital quality based on a previously validated claims-based quality index was estimated.

METHODS

MEDULA, a nationwide integrated system shared between general health insurance and health care providers, was used for the analysis. Claims from 17,800 pharmacies, 5,600 general practitioners, 4,500 medical centers, 1,200 government hospitals, and 338 private hospitals are recorded in the data, covering over 80% of the population in Turkey.

All patients aged 18–99 years who underwent CABG surgery between April 1, 2009 and October 1, 2010 were identified using procedure codes from the International Classification of Diseases Tenth Revision Clinical Modification. Patients were assigned to “standard-therapy” or “excess-use” groups if they had only one or more than one coronary angiography, respectively, within 3 months of their first CABG diagnosis date (index date) during the identification period. Patients were required to be continuously enrolled 3 months prior to the index date and 12 months following the index date.

The first aim was to examine the extent to which overuse of coronary angiography varied geographically across cities and hospitals. The second aim was to assess the association of coronary angiography excess use with operational mortality, higher expenditures,

and hospital quality. Descriptive analyses were performed to compare risk factors, including demographic, clinical, and provider characteristics of coronary angiography patients. Demographic information regarding age, gender, and geographic region was available in the dataset.

The Elixhauser Index score was calculated to measure comorbidity burden [14]. This index is based on a comprehensive set of 30 International Classification of Diseases Ninth Revision Clinical Modification comorbidity flags. The detailed list is provided in the Table 4 of Appendix. To conceptually identify important comorbidities, the Elixhauser Index attempted to exclude information relating to other aspects of a patient's condition. For example, a secondary diagnosis is considered to be comorbid only when it is not directly related to the principal diagnosis.

Complications were eliminated by excluding codes that reflect acute conditions. Therefore, in the Elixhauser Index, a number of diagnoses that may have been considered comorbidities were not counted, because certain conditions, such as pneumonia, pleural effusion, urinary tract infection, cardiac arrest, cardiogenic shock, and respiratory failure, were not distinguishable from complications that may have resulted from diagnostic or therapeutic interventions during hospitalization. Unimportant comorbidities were also eliminated because those such as benign prostatic hypertrophy, inguinal hernia, and diverticulitis do not significantly impact resource use or mortality, if they were not the principal diagnosis. Current coding for the Elixhauser Index is available from the Agency for Healthcare Research and Quality and is widely used in outcomes research [15].

Acuity admission and the Elixhauser Index score were used as a proxy for severity. The

cardiac surgery volume and teaching hospital status were derived as provider characteristics. Health care utilization, mortality and health care costs were available in the dataset. Health care reimbursement amounts were converted to Euros. (1€ = 2.34 TRY, May 15, 2013).

This article does not contain any studies with human or animal subjects performed by any of the authors.

Statistical Analysis

Paired *t* tests and Chi-square tests were used to compare the demographic, clinical, and provider characteristics between the two groups: standard-therapy group and excess-use group. To estimate risk-adjusted differences in mortality and annual health care costs with the overuse of angiography, the propensity score matching (PSM) method was used. This technique, employed by the predicted probability of group membership, isolates the observed bias from the estimation [16]. Following previously published guidelines for choosing the most appropriate matching technique for the present data, one-to-one matching with caliber was used [17]. Caliber was selected as 25% of the standard errors of the estimated propensity score.

Using regression analysis, mortality rates and total health care costs for patients with standard therapy and excess use were also estimated. In particular, Cox regression was used for operational mortality estimation, and generalized linear models were used for total health care cost estimation for both groups.

Hospital quality was characterized by a previously validated composite score, which combines operational mortality with hospital volume information using Bayesian techniques [18]. Hospital procedure volume was assessed as the total number of procedures performed by

each hospital. Operational mortality was defined as death occurring before discharge or within 30 days of surgery. The authors calculated risk-adjusted hospital mortality using regression analysis. After testing the fit of several transformations, hospital volume was modeled as natural log of the continuous volume variable. Using this regression model, the authors estimated the volume-predicted mortality for each hospital, and ratio of the number of actual to expected deaths was then determined. The number of expected deaths was the sum of the patients of the predicted probability of death, derived from a logistic regression model estimated for all patients undergoing surgery. The dependent variable in the logistic regression was death, and the independent variables were patient demographic and clinical factors. The derived index is presented in quartiles to rank low- to high-quality hospitals. Since this index combines information from multiple quality domains into a single measure, it has been referred to as the “gold standard” for hospital performance comparisons on US national standards of safety, quality, and efficiency that are most relevant to patients and payers [19–21].

All statistical analyses were conducted using SAS® V.9.3 (SAS Institute Inc., North Carolina, USA) and STATA® V11 (StataCorp LP, Texas, USA). In particular, SAS V.9.3 is used for data management, and STATA V11 is used for statistical analysis.

RESULTS

A total of 20,126 patients satisfied all inclusion criteria, of which, 88.12% ($n = 17,734$) underwent CABG surgery after one coronary angiography (standard-therapy group), and 7.27% ($n = 1,464$) had more than one coronary angiography (excess-use group)

within 3 months prior to CABG surgery. The distribution of excess use is presented in Fig. 1. Few CABG surgery patients (4.61%) did not utilize coronary angiography prior to surgery.

Most subjects were 45–64 years, and 27.01% of the cases were female. Patients most frequently resided in the Marmara Region (36.64%), followed by Central Anatolia (25.36%), the Mediterranean (12.47%), and the Aegean region (10.55%). Nearly one-third of the sample had comorbidity scores ≥ 2 (32.17%). Less than 1% of these patients were admitted into the emergency care settings. The majority of surgeries were performed in high-volume hospitals (58.75%), and 11.16% of the surgeries occurred in teaching hospitals (Table 1).

Geographic variation in coronary angiography use is presented in Fig. 2. To increase the reliability of the estimate, cities with <20 angiography procedures were not taken into consideration in the rates. The proportion of CABG surgery patients with excess use was the highest in Erzurum (13.36%), followed by Batman (12.28%), and Antalya (11.95%). Thirty-six out of 81 cities did not have centers for coronary angiography, and 1,288 patients underwent CABG surgery without having a coronary angiography. A total of 33.17%

Fig. 1 Distribution of excess use of angiography (>1 angiography) for patients who underwent CABG surgery in hospitals across Turkey. CABG coronary artery bypass graft

Table 1 Sample characteristics

Demographics	CABG patients (<i>n</i> = 20,126)	
	<i>n</i>	%
Number of patients	20,126	
Patient characteristics		
Age mean (SD)	62.13 (9.70)	
18–30	16	0.08
31–44	689	3.42
45–64	10,992	54.62
65–74	6,273	31.17
≥75	2,156	10.71
Gender (% female)	5,436	27.01
Admission acuity (% emergency care)	13	0.06
Elixhauser Index score (≥2)	6,474	32.17
Regions		
Aegean	2,124	10.55
Marmara	7,374	36.64
Central Anatolia	5,084	25.26
Mediterranean	2,509	12.47
Black Sea	1,222	6.07
Eastern Anatolia	589	2.93
Southeastern Anatolia	1,224	6.08
Provider characteristics		
Teaching hospital	2,246	11.16
Hospital volume quartiles		
Q1 (low)	1,465	7.28
Q2	2,234	11.10
Q3	4,602	22.87
Q4 (high)	11,825	58.75

CABG Coronary artery bypass graft, SD standard deviation

(*n* = 68) of hospitals had excess use rates below 5%, while 5.37% (*n* = 11) of hospitals had excess use rates exceeding 20% (Fig. 3).

Compared with standard-therapy patients, excess-use patients were less likely to be between the ages of 45 and 64 years (51.50% versus 54.85%, $P < 0.02$), female (25.27% versus 27.30%, $P < 0.1$), to reside in the Southeastern Anatolia region (4.30% versus 6.24%, $P < 0.003$), and have their surgery in high-volume hospitals (Table 2). However, patients in the excess-use group resided in the Mediterranean region more frequently than those in the standard-therapy group (15.57% versus 12.28%, $P < 0.001$). Patients who underwent CABG surgery in teaching hospitals were more likely to have more than one coronary angiography prior to surgery (14.41% versus 10.43%, $P < 0.0001$).

After PSM, 1,464 patients were matched between patients in the excess-use and standard-therapy groups. Matched patients were similar in terms of their demographic, clinical, and provider characteristics (Table 3). Over the matched sample, where differences in demographic, clinical, and provider differences were adjusted, operational mortality (7.4% versus 5.4%, $P < 0.03$) and annual health care costs were significantly higher for the excess-use group relative to the standard-therapy group (€8,737 versus €7,963, $P < 0.01$).

After controlling for baseline demographic and clinical factors in the regression models, the results were consistent with PSM models. Operational mortality (5.7% versus 4.4%, $P < 0.01$) and annual health care costs (€8,634 versus €7,852, $P < 0.01$) were significantly higher for the excess-use group relative to the standard-therapy group.

Hospital quality was strongly associated with excess use. Only 7.0% of patients in hospitals with the highest quality rating were in the excess-use group within 30 days of CABG surgery, whereas the rate was significantly higher for low-quality hospitals (9.5%, $P < 0.01$; Fig. 4).

Fig. 2 Excess use of coronary angiogram (>1 angiography) for CABG patients across cities in Turkey. *CABG* coronary artery bypass graft, *Q* quarter

Fig. 3 Hospital distribution in the probability of excess use (>1 angiography) adjusted by patient characteristics

For the complete overview of the study population, patients who did not receive the angiography were also compared with the main study groups. After applying risk adjustment, standard-therapy patients use had lower mortality rates (3.96% versus 6.01%, $P < 0.010$) and incurred lower annual health care costs (€7,850 versus €8,081, $P < 0.010$) relative to patients who did not have angiography. Patients with excess use of angiography incurred higher annual health care costs (€8,695 versus €8,148, $P < 0.010$) and had no significant operational mortality rate advantage (5.74% versus 6.09%, $P = 0.675$), relative to patients without angiography use.

DISCUSSION

Several studies reported on variations in the utilization of cardiac procedures [20–25]. These studies showed that variation is related to age, gender, racial, and geographic factors.

In this study, angiography utilization in a disease-specific (CABG surgery) cohort of patients with uniform insurance coverage in Turkey was examined. Results determined that after adjusting for demographic and clinical factors, there was significant variation in coronary angiography use. Regional practice patterns emerged, showing that more procedures were performed in cities such as Erzurum, Batman and Antalya, relative to the rest of Turkey.

Current guidelines for patients undergoing assessment for obstructive coronary artery disease are designed to limit the number of invasive angiographies and thereby enhance the diagnostic yield of cardiac catheterization [26]. However, a substantial increase in these procedures has contributed to a rise in medical costs. Several factors are responsible for this increase, including wider availability of technology, increased demand by patients and physicians, and favorable reimbursements [27].

Table 2 Demographic, clinical, and provider characteristics of CABG patients with (excess-use group) and without (standard-therapy group) excess use of angiography

Demographics	Standard-therapy group		Excess-use group		<i>P</i> value
	<i>n</i>	%	<i>n</i>	%	
Number of patients	17,374		1,464		
Patient characteristics					
Age mean (SD)	62.16 (9.63)		62.36 (9.99)		0.4614
18–30	12	0.07	2	0.14	0.3624
31–44	572	3.29	58	3.96	0.1712
45–64	9,530	54.85	754	51.50	0.0134
65–74	5,419	31.19	481	32.86	0.1871
≥75	1,841	10.60	169	11.54	0.2595
Gender (% female)	4,743	27.30	370	25.27	0.0941
Admission acuity (% emergency care)	10	0.06	1	0.07	0.8701
Elixhauser index	5,513	31.73	527	36.00	0.0008
Regions					
Aegean	1,818	10.46	152	10.38	0.9221
Marmara	6,347	36.53	545	37.23	0.5959
Central Anatolia	4,398	25.31	346	23.63	0.1550
Mediterranean	2,134	12.28	228	15.57	0.0003
Black Sea	1,078	6.20	85	5.81	0.5428
Eastern Anatolia	515	2.96	45	3.07	0.8126
Southeastern Anatolia Region	1,084	6.24	63	4.30	0.0029
Provider characteristics					
Teaching (%)	1,812	10.43	211	14.41	<0.0001
Hospital volume quartiles					
Q1 (low)	1,241	7.14	110	7.51	0.5974
Q2	1,882	10.83	198	13.52	0.0016
Q3	3,955	22.76	393	26.84	0.0004
Q4 (high)	10,296	59.26	763	52.12	<0.0001

CABG Coronary artery bypass graft, SD standard deviation

In Turkey, due to the implementation of the Health Transformation Program by the Ministry of Health in the last decade, the health status of the Turkish population has improved

significantly [28]. Therefore, the rise in procedure utilization is expected. However, the association with excess use and hospital quality is of particular interest. Often, coronary

Table 3 Demographic, clinical and provider characteristics of CABG patients with and without excess use of angiography after propensity score matching

Demographics	Standard-therapy group		Excess-use group		<i>P</i> value
	<i>n</i>	%	<i>n</i>	%	
Number of patients	1,464		1,464		
Patient characteristics					
Mean age (SD)	62.58 (9.8)		62.36 (9.99)		0.5475
18–31	3	0.20	2	0.14	0.5392
31–44	57	3.89	58	3.96	0.8908
45–64	754	51.50	754	51.50	0.9999
65–74	481	32.86	481	32.86	0.9999
≥75	169	11.54	169	11.54	0.9999
Gender (female, %)	370	25.27	370	25.27	0.9999
Admission acuity (% emergency care)	1	0.07	1	0.07	0.9999
Elixhauser index (% with 2 and above)	526	35.93	527	36.00	0.9555
Regions					
Aegean	152	10.38	152	10.38	0.9999
Marmara	545	37.23	545	37.23	0.9999
Central Anatolia	346	23.63	346	23.63	0.9999
Mediterranean	228	15.57	228	15.57	0.9999
Black Sea	85	5.81	85	5.81	0.9999
Eastern Anatolia	45	3.07	45	3.07	0.9999
Southeastern Anatolia Region	63	4.30	63	4.30	0.9999
Provider characteristics					
Teaching (%)	210	14.34	211	14.41	0.9392
Hospital volume					
High volume	763	52.12	763	52.12	0.9999

SD standard deviation

angiography is done in the urban centers. When patients move to higher volume hospitals for CABG surgery, the procedure is repeated, yielding excess use of this invasive and risky procedure. Problems may arise when physicians fear missing something or doing too little. This attitude has developed a culture where individuals feel that doing more tests and

knowing more are always the proper course. Therefore, communication between angiography centers and health care professionals must become more efficient, in order to determine which patients should be subjected to the cost and risk of an angiogram. Patients may question their doctors about the need for the second test, as well as any risks or

Fig. 4 Excess use of coronary angiogram (>1 angiography) and hospital quality. *Q* quarter

alternative options. The annual health care costs for the excess-use group were 9.7% higher than for standard-therapy group. Mortality rates were 1.37 times higher.

Hospital quality was assessed using a previously validated composite score, which has been applied by a large group of coalitions in the United States [19, 21]. Traditional quality indicators, whether they are based on structure, process, or direct outcomes measures, have significant limitations. For example, hospital volume is important for high-risk procedures but does not reliably predict performance for individual hospitals. Process measures often fail to explain observed variations in hospital mortality rates. Direct outcomes measures, because of sample size limitations, are often imprecisely estimated and do not produce a reliable estimate of hospital performance. The composite measure used in this study has the potential to obviate these limitations, because it combines information from surgical volume and operational mortality into a single summary measure. This study presents a negative relationship between high-quality hospitals and excess use of coronary angiography.

Numerous studies have been done to evaluate factors that may influence the results of a variety of surgical procedures. Almost

invariably, when assessed, surgeon experience is an important factor in determining the likelihood of successful outcomes from surgery. For example, in shoulder replacement procedures, a surgeon who performs 30 replacements over 6 years is considered “high volume” [29]. These doctors had lower complication rates and their patients had shorter hospital stays than “low volume” surgeons. In hip replacement surgery, surgeons who performed fewer than 30 hip replacements each year had more patients requiring revision surgery [30]. In another study, 5 years of scoliosis surgery experience did not improve outcomes [31]. Therefore, it is difficult to define a specific number of procedures that deem a surgeon proficient. In the present study, the authors empirically determined the effect of the volume of procedures by including them in the hospital quality index.

The present study has several strengths. To the authors’ knowledge, this is the first study in Turkey that includes a large, diverse, and geographically varied sample of patients who received coronary angiography before CABG surgery. It is also the first study that shows the relationship between hospital quality and the excess use of coronary angiography. Excess costs associated with angiography overuse and operational mortality are also presented for the first time in Turkey.

Data were limited in their clinical information related to disease severity in coronary angiography patients. The Elixhauser Index and admission acuity were used in the attempt to control for differences. These measures are not representative of disease severity; therefore, the impact of severity on coronary angiography excess use may be underestimated. Although claims data are extremely valuable in revealing the real-world practice of procedures and determining

associated costs, these data are collected for payment purposes rather than research. Presence of a diagnosis code on a medical claim is not necessarily proof of disease presence, as diagnoses may be miscoded. Random miscoding would not affect the present results; however, if it is systematically related to hospitals or geographic regions, then the study results would be biased. The magnitude of miscoding and its effect on the extent of variation remains unclear.

Risk adjustment was performed using PSM, and although the method is widely used in outcomes research, it controls only observed bias. Regression analysis is another technique to control for observable bias. There has been some discussion about which method should be chosen to remove observable bias [32]. Proponents of the PSM method outline several advantages of the technique over regression analysis. First, without involving the outcome variable in the selection process, PSM can design observational studies in an analogous way, compared with the way randomized clinical trials are designed [33]. Regression analysis uses the outcome as a left-hand-side variable, which is not supposed to be available during randomization. Second, confounding by treatment variables is often the main challenge to validity, and the propensity score focuses directly on treatment variables [34]. Third, a matched analysis can eliminate non-comparable exposed subjects [35]. Finally, PSM provides robust estimates when there are relatively few outcomes to compare with the number of potentially few outcomes [36–38]. Proponents of regression analysis, however, focus on statistical advances in regression literature [39, 40]. Deciding on a matching algorithm and obtaining standard errors for inference through matching are more complicated than conducting regression analysis. Little of the existing literature examines

this process. Thus, careful regression analysis with good controls and flexible functional forms is often the most accurate.

In this paper, the authors applied both PSM and regression analysis, and the results were similar. Shah et al. compared the PSM method and traditional regression modeling in observational studies. Among 78 exposure-outcome associations in 43 studies evaluated, statistical significance differed in only 10% of cases [41]. Stürmer et al. [42] compared 69 studies and found that in only 13% of the studies, PSM estimates differed by more than 20% from the regression model. In the present example, due to excess use, 1.37 times the associated risk increase in operational mortality in PSM results decreased to 1.29 times in traditional regression analysis. Associated cost differences in PSM analysis increased from €774 to €782, compared with traditional regression analysis. PSM and traditional regression analyses yielded significant differences in outcomes between the standard-therapy and excess-use groups. Consistent with the Shah et al. and Stürmer et al. studies, comparison estimates between the two techniques were not significantly different.

Unobserved bias can occur due to missing disease severity information and the use of advanced techniques, such as the instrumental variable approach [43]. However, these techniques are bounded by their own limitations [44, 45].

CONCLUSION

Efforts to curb the growth of health care spending in Turkey inevitably require a decrease in the variation of quality health care. A systematic examination of excess use of invasive procedures is an essential step in targeting cost-reduction

efforts along with improving health care quality. By analyzing real-world data, this study showed that there exists a variation in coronary angiography use in Turkey. Excess use of coronary angiography prior to CABG surgery is associated with higher operational mortality expenditures and lower hospital quality.

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Compliance with Ethics Guidelines. This article does not contain any studies with human or animal subjects performed by any of the authors.

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APPENDIX

See Table 4.

Table 4 List of comorbid conditions in the Elixhauser index

Congestive heart failure
Cardiac arrhythmias
Valvular disease
Pulmonary circulation disorders
Peripheral vascular disorders
Hypertension (complicated and uncomplicated)
Paralysis
Other neurological disorders
Chronic pulmonary disease
Diabetes without chronic complications
Diabetes with chronic complications
Hypothyroidism
Renal failure
Liver disease
Chronic peptic ulcer disease (includes bleeding only if obstruction is also present)
HIV and AIDS
Lymphoma
Metastatic cancer
Solid tumor without metastasis
Rheumatoid arthritis/collagen vascular diseases
Coagulation deficiency
Obesity
Weight loss
Fluid and electrolyte disorders
Blood loss anemia
Deficiency anemia
Alcohol abuse
Drug abuse
Psychoses
Depression

The original Definitions of comorbidities were given in a 1998 article by Elixhauser et al. [14]; however, these definitions have been updated. See (<http://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp>) (accessed May 28, 2013) to reflect the changes in the codes to define the comorbidities. We used the updated version in this study

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