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IMPACT OF COMPUTED TOMOGRAPHY CORONARY ANGIOGRAPHY ON OTHER DIAGNOSTIC TESTS

Elena Berti
Agenzia Sanitaria e Sociale Regionale - Regione Emilia-Romagna (ASSR-RER)
e-mail: eberti@regione.emilia-romagna.it

Laura Maria Beatrice Belotti
Agenzia Sanitaria e Sociale Regionale - Regione Emilia-Romagna (ASSR-RER)

Filippo Cademartiri
Azienda Ospedaliero-Universitaria, Parma

Tiziana Giovannini, Rossana De Palma, Roberto Grilli
Agenzia Sanitaria e Sociale Regionale - Regione Emilia-Romagna (ASSR-RER)

Objectives: Information on the impact of computed tomography coronary angiography (CTCA) on patterns of care is scarce. In particular, it is not clear if, and to what extent, its adoption actually leads to a reduction in the use of other diagnostics tools. The aim of this study was to evaluate whether the adoption of CTCA in Emilia-Romagna (an Italian region with a population of 4.4 million) had any effect on utilization rates of myocardial perfusion scintigraphy (MPS) and coronary angiography (CA).
Methods: Interrupted time series (ITS) were applied to monthly volumes of MPS and CA tests performed from 2003 to 2010, to assess trends in usage rates for those procedures before and after CTCA was adopted by all the healthcare organizations operating in the region.
Results: After an increase in the first year of CTCA introduction, its use remained stable over the study period. After September 2006, a significant decrease in MPS volumes (31 percent; $p < .0001$) and a much less tangible decrease in CA volumes (5 percent; $p < .0001$), were detected by ITS analyses.
Conclusions: This study demonstrates that the use of CTCA had a greater impact on MPS usage rates than on CA.

Keywords: Multislice computed tomography, Coronary angiography, Myocardial perfusion imaging, Ischemic heart disease

Rapid technological advances in cardiovascular imaging technology have led to explosive growth in noninvasive coronary imaging. Computed tomography coronary angiography (CTCA) $\geq$ 64 slice shows better diagnostic accuracy (sensitivity: 97.2 percent; specificity: 87.4 percent) (13) than other diagnostic tests, such as myocardial perfusion scintigraphy (MPS) (sensitivity 92 percent; specificity 74 percent) (12), stress echocardiography (sensitivity 80 percent; specificity 84 percent) (7), and magnetic resonance imaging (MRI) (sensitivity 87.1 percent; specificity 70.3 percent) (15).

Since its introduction, appropriate use of CTCA has been proposed to exclude coronary artery disease (CAD) in low/intermediate risk patients (11,16), although evidence of improved outcomes and cost-effectiveness compared with other noninvasive diagnostic tests has never been demonstrated (14,17). According to the diagnostic algorithm proposed by the American College of Cardiology and the American Heart Association (8), coronary angiography (CA) is indicated when symptoms, clinical findings or results from noninvasive tests suggest a high risk of CAD and future cardiac events. So far research on CTCA has focused on the diagnostic performance of continuously evolving versions of the device (from 16 slices to 320 slices) (10). However, little attention has been paid to the actual impact on clinical practice styles of CTCA availabilities.

In this study, we assess the clinical impact of CTCA on MPS and CA volumes in suspected/known CAD patients (irrespective of cardiovascular risk and symptoms) in Emilia-Romagna, an Italian region with a population of 4.4 million. We expected both a decrease in MPS volumes (because of specialist preference for a diagnostic test with better diagnostic accuracy), and a reduction in CA volumes, due to CTCA use as a gatekeeper to CA. Moreover, we supposed that CTCA adoption could lead to a gradual change in the trend of use of MPS and CA after CTCA diffusion rather than a rapid change.

METHODS

Monthly volumes of MPS and CA tests performed in Emilia-Romagna between January 2003 and December 2010 were retrieved from the regional databases of the outpatient specialist care and the hospital discharge records. The following ICD-9-CM codes were used to determine the diagnostic procedures performed: 92.05.1, 92.05.2, 92.09.1, 92.09.2 for MPS and 88.55, 88.56, 88.57 for CA. As CTCA had no specific ICD-9-CM coding, annual volumes for this procedure were retrieved from the information system of each individual diagnostic facility.

To assess the impact of CTCA on practice patterns, the time frame of the study was divided into two periods: before and after full adoption of CTCA. Operationally, full adoption was considered to be achieved in September 2006, when all the regional Local Health Districts (i.e., the healthcare organizations responsible for the provision of care on a provincial basis) had one CTCA device in place on average. Overall, for our analysis we relied on 44 and 52 monthly observations, before and after September 2006, respectively.

Data were analyzed by using interrupted time series (ITS). After controlling for the effects of seasonality through the moving average method, the assessment of change in volumes before and after CTCA adoption was performed applying regression models. Two regression models were used, assigning the monthly number of MPS or CA, respectively, as the dependent variable, and three dummy variables as covariates (2;3;6). In detail, having set to zero the time point at which CTCA was adopted (September 2006), the first dummy (representing the slope before CTCA) was stepped backward and the second (slope after CTCA) stepped forward. Moreover, the latter was set to 0 before CTCA adoption and 1 after it. The difference between before and after slope regression coefficients represents the "change in slope" attributed to CTCA, while the "change in level" coefficient is calculated by the model. Autocorrelation was explored by using the Durbin-Watson statistic and the Cochrane-Orcutt iterative procedure was used for adjustment.

Analyses were performed using SAS 9.1 (SAS Institute, Cary, NC).

RESULTS

During the time frame 2003–08, CTCA increased until 2006 and became stable afterward; MPS volumes increased until 2006 and decreased thereafter; CA volumes increased until 2007 and then decreased slightly (Table 1).

Table 1. Myocardial perfusion scintigraphy (MPS), computed tomography coronary angiography (CTCA) and coronary angiography (CA) volumes from 2003 to 2010 in Emilia-Romagna.

	MPS	CTCA	CA
2003	8 570	–	17 997
2004	9 240	–	20 271
2005	9 630	957	21 609
2006	9 982	1 368	22 091
2007	9 476	1 361	22 839
2008	7 988	1 234	22 334
2009	7 158	1 411	21 189
2010	6 929	1458	21 238

Monthly volumes of MPS and CA tests performed in Emilia-Romagna hospitals are shown in Figure 1 (bright gray line), along with the seasonal and three-monthly moving average adjusted time series (dot line and black line, respectively).

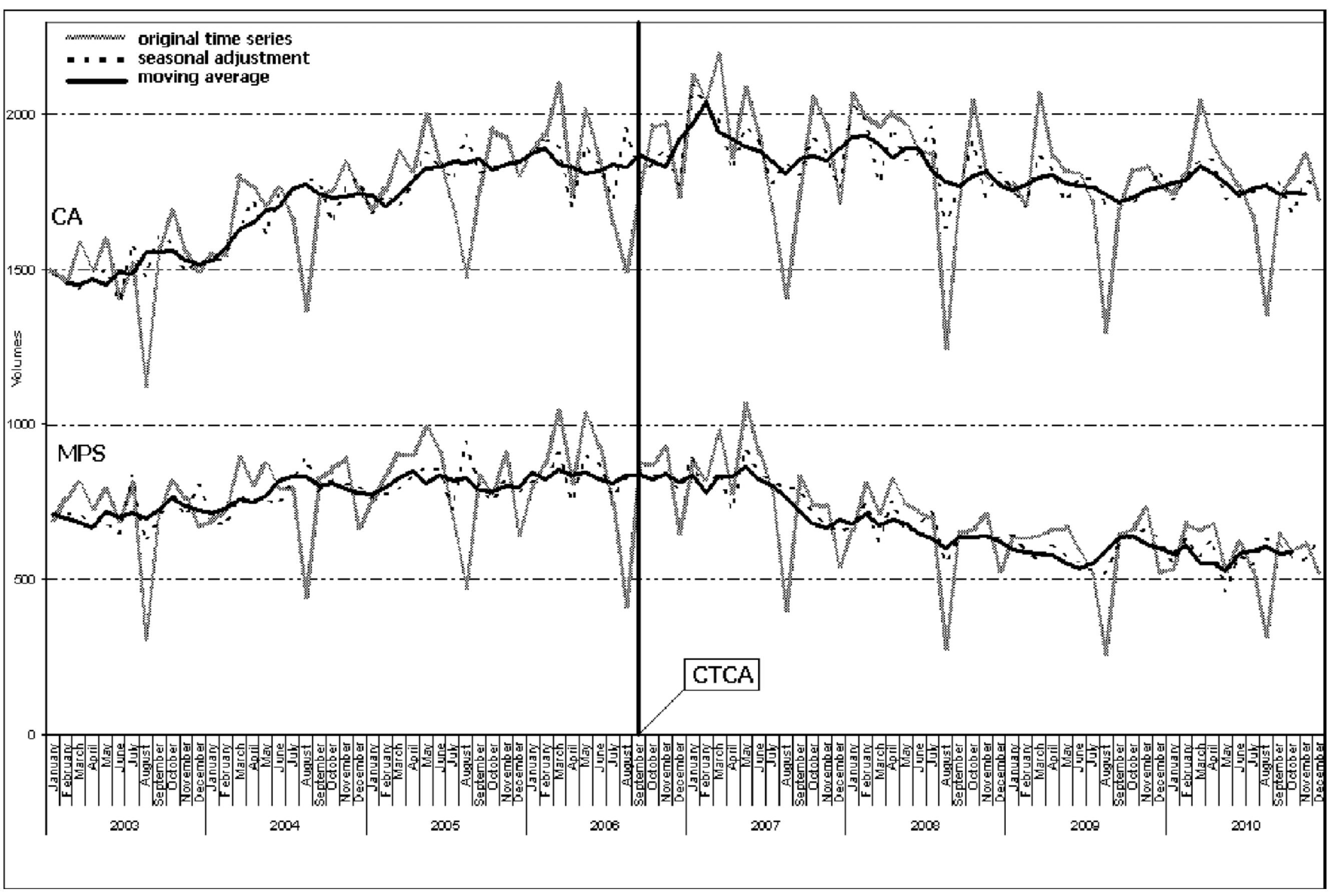

Figure 1. Monthly volumes of myocardial perfusion scintigraphy (MPS) and coronary angiography (CA) (original and adjusted time series) performed in Emilia–Romagna hospitals over the period January 2003 - December 2010.

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Table 2. Results of interrupted time series analysis to asses the impact of CTCA on myocardial perfusion scintigraphy (MPS) and coronary angiography (CA) procedures performed in Emilia-Romagna.

Dependent variable	Covariates	Coefficients (β)	*p* value
Number of MPS	Intercept	189	<0.0001
	Slope before CTCA	2.67	0.019
	Slope after CTCA	−6.15	<0.001
	Change in slope	−8.84	<0.0001
	Change in level	−3.52	0.8846
Number of CA	Intercept	337	<0.0001
	Slope before CTCA	9.05	<0.0001
	Slope after CTCA	−4.02	0.0002
	Change in slope	−13.17	<0.0001
	Change in level	17.95	0.5497

A volume decrease of MPS and CA is clearly evident after the diffusion of CTCA in September 2006. It is particularly marked for MPS, whose volumes dropped by 31 percent (from 9,982 to 6,929 procedures) between 2006 and 2010.

These observations were confirmed by ITS analyses (Table 2): CTCA diffusion was associated with a “change in slope,” affecting both MPS ($\beta = -8.84$; p value $< .0001$) and CA ($\beta = -13.17$; p value $< .0001$). Slope coefficients before and after CTCA diffusion had opposite signs and were both statistically significant. As expected, no “change in level” was detected for either procedure ($\beta = -3.52$; p value $= .8846$ and $\beta = 17.95$; p value $= .5497$, respectively).

Serial autocorrelation was evident for both diagnostic procedures: Durbin Watson test value (D) for MPS was 0.493 ($p < .0001$) and 0.445 ($p < .0001$) for CA. The Cochrane Orcutt iterative approach succeeded in correcting for autocorrelation for MPS (D = 1.960; $p = .3276$), but it did not for CA (D = 1.561; $p = .0082$). This could have led to underestimation of standard errors and overestimation of CTCA effects over CA.

DISCUSSION

Our findings suggest that CTCA had a greater impact on MPS utilization rates than on CA: after September 2006, CTCA volumes remained quite stable over time, MPS volumes had a statistically significant decrease of 31 percent while CA volumes of 5 percent only.

The impact of CTCA on clinical practice has frequently been the object of speculation, asserting that, in view of its high negative predictive value compared with traditional noninvasive diagnostic tests, the number of other noninvasive tests should have been decreased because of CTCA capacity to better select patients for potential revascularization. However, until now these hypotheses have never been confirmed. To best of our knowledge, few studies so far have explored how CTCA availability affects pattern of care for patients with CAD.

Auseon et al. (1) compared the number of diagnostic and therapeutic procedures performed in a single center for suspected CAD for 5 years before and 1 year after 64-slice CTCA introduction in 2005 (1,053 CTCA total procedures performed). The authors calculated the absolute number of procedures performed and normalized the rates for the number of total visits. They found that, during the first year of CTCA introduction, the volumes of cardiac catheterization and coronary interventions were not altered and the volumes of overall stress tests were decreased.

Wagdi and Alkadhi (18) evaluated retrospectively the impact of CTCA on the appropriate usage of CA in two hospitals (one private and one public) 1 year before and 1 year after the introduction of CTCA. They found a significant drop in CA examinations in patients with suspected CAD showing any significant coronary disease (19 percent in 2006 versus 10 percent in 2007; $p < .0001$).

Chow et al. (4) found a decreased number of CA performed in a single tertiary-care center after the implementation of a cardiac CT program, from 31.5 percent to 26.8 percent ($p < .001$). These findings were significantly different ($p = .003$) from three other centers that were studied, where normal CAs remained unchanged (30 percent to 31 percent).

Since its introduction as a tool for noninvasive coronary imaging, CTCA has undergone significant clinical validation against CA regarding feasibility and diagnostic performance for the assessment of luminal stenosis. However, data demonstrating benefits on outcomes and supporting widespread usage of this diagnostic modality are still lacking, as pointed out by a “decision memo” for CTCA coverage decision by US Centers for Medicare and Medicaid Services stating “there is uncertainty regarding any potential health benefits or patient management alterations from including CTCA in the diagnostic work-up of patients who may have coronary artery disease; no adequately powered study has established that improved health outcomes can be causally attributed to CTCA for any well-defined clinical indication, and the body of evidence is of overall limited quality and limited applicability in community practice”(5).

Waiting for the evidence from comparative effectiveness research on CTCA, we applied ITS analyses to this “before and after design” study, to confirm our expectation of gradual change in volumes of MPS and CA tests performed after CTCA diffusion (measured by the change in slope). One of the explanations of our findings could be that cardiologists became more confident with CTCA technology, thus reducing the number of patients referred to scintigraphy due to MPS lower diagnostic accuracy. Coronary angiography volumes decreased only slightly, perhaps because the number of CTCA performed was still too small (1,500/year) to affect the total number of CA executed (20,000/year) or the number of people not referred to CA because of a negative CTCA result counterbalanced the number of people wrongly referred to CA because of a false positive CTCA result. A further explanation might be that

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referral cardiologists were still more confident in CA in view of the possibility of on-line revascularization. Finally, it could be argued that the observed MPS decrease was due to the uptake of other innovative imaging technologies or to the reduction in Technetium 99m availability, but the latter occurred only after 2008, that is, 1.5 years after our observations (9).

This study has of course relevant limitations. First, we investigated the effects on CAD management of CTCA diffusion without really going into depth about the CTCA, MPS, and CA phenomena (e.g., including information about patients, indications, technologies, procedure results, and so on). We just assumed that in September 2006 CTCA was widespread, as its annual volumes remained quite stable since that date. The underlying reason was that we had detailed clinical and instrumental information just for CA (a regional coronary angiography clinical database started in 2002), a regional CTCA clinical database was launched in 2007 only and any MPS clinical database has never been developed.

Second, our study did not investigate other diagnostic modalities for CAD such as stress-echo and MRI, that could have affected the decrease in MPS use. We tried to analyze stress-echo volumes, but encountered coding problems that led to an underestimation of the total number of tests performed and MRI was performed by only one hospital with very low volumes.

Third, the fact that usage is heavily dependent on technology availability could have invalidated our results: we took a picture when every Local Health District had one machine on average but it can be expected that the number of CTCA performed will increase with technology diffusion.

At last, our study did not consider all possible consequences deriving from the adoption of CTCA: the therapeutic impact (e.g., the number of CA/revascularization procedures either prevented or incurred and a change in drug regimen), safety issues (e.g., radiation exposure and adverse events), and costs. Each of these aspects would deserve a comparative research study with traditional diagnostic tests.

In conclusion, the scientific literature on CTCA is still largely dominated by observational studies, focused mainly on diagnostic accuracy rather than on clinical impact on coronary artery disease management. The present study is the first one exploring the latter aspect contributing to knowledge by using interrupted time series methodology in a regional context. However, further research is needed to confirm our findings and to investigate real CTCA effectiveness on patient outcomes, compared with other traditional tests.

CONTACT INFORMATION

Elena Berti, MD, Laura Maria Belotti, Statistician, Tiziana Giovannini, Biologist, Rossana De Palma, MD, Head of Clinical Governance Unit, Roberto Grilli, MD, Director, Agenzia Sanitaria e Sociale Regionale - Regione Emilia-Romagna (ASSR-RER), Bologna, Italy

Filippo Cademartiri, MD, PhD, Department of Radiology, Azienda Ospedaliero-Universitaria, Parma, Italy

CONFLICTS OF INTEREST

All authors report they have no potential conflicts of interest.

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