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Reduction in downstream test utilization following introduction of coronary computed tomography in a cardiology practice

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Abstract To compare utilization of non-invasive ischemic testing, invasive coronary angiography (ICA), and percutaneous coronary intervention (PCI) procedures before and after introduction of 64-slice multi-detector row coronary computed tomographic angiography (CCTA) in a large urban primary and consultative cardiology practice. We utilized a review of electronic medical records (NotesMD®) and the electronic practice management system (Megawest®) encompassing a 4-year period from 2004 to 2007 to determine the number of exercise treadmill (TME), supine bicycle exercise echocardiography (SBE), single photon emission computed tomography (SPECT) myocardial perfusion stress imaging (MPI), coronary calcium score (CCS), CCTA, ICA, and PCI procedures performed annually. Test utilization in the 2 years prior to and 2 years following availability of CCTA were compared. Over the 4-year period reviewed, the annual utilization of ICA decreased 45% (2,083 procedures in 2004 vs. 1,150 procedures in 2007, $P < 0.01$) and the percentage of ICA cases requiring PCI increased (19% in 2004 vs. 28% in 2007, $P < 0.001$). SPECT MPI decreased 19% (3,223 in 2004 vs. 2,614 in 2007 $P < 0.02$) and exercise stress treadmill testing decreased 49% (471 in 2004 vs. 241 in 2007 $P < 0.02$). Over the same period, there were no significant changes in measures of practice volume (office and hospital) or the annual incidence of PCI (405 cases in 2004 vs. 326 cases in 2007) but a higher percentage of patients with significant disease undergoing PCI 19% in 2004 vs. 29% in 2007 $P < 0.01$. Implementation of CCTA resulted in a significant decrease in ICA and a corresponding significant increase in the percentage of ICA cases requiring PCI, indicating that CCTA resulted in more accurate referral for ICA. The reduction in unnecessary ICA is associated with avoidance of potential morbidity and mortality associated with invasive diagnostic testing, reduction of downstream SPECT MPI and TME as well as substantial savings in health care dollars.

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Abbreviations and acronyms

CAD	Coronary artery disease
CCS	Coronary calcium score
CCTA	Coronary computed tomographic angiography
CLCD	California local coverage determination
CT	Computed tomography
ECG	Electrocardiogram
ICA	Invasive coronary angiography
MDCT	Multidetector computed tomography
MPI	Myocardial perfusion imaging
PCI	Percutaneous coronary intervention
SBE	Supine bicycle exercise echocardiography
SPECT	Single proton emission computed tomography
TME	Treadmill exercise testing

Introduction

Cardiac risk stratification and identification of patients requiring intensive medical therapy versus those who might benefit from revascularization has in part relied on myocardial perfusion imaging [1, 2]. The substantial morbidity, mortality, and economic costs associated with coronary artery disease (CAD) have stimulated the development and adoption of alternative methods. Even though several prospective studies have concluded that MPI for patients without limiting symptoms can serve as a gatekeeper to ICA [3–7] there is an opportunity for more specific and sensitive referral for invasive angiography.

Noninvasive coronary computed tomographic angiography (CCTA), which visualizes coronary artery stenosis directly (rather than ischemia), has been proposed as an alternative noninvasive imaging modality for evaluation of patents with known or suspected CAD [8]. Studies comparing 64-slice CCTA to invasive coronary angiography (ICA) as the gold standard have reported a high (>95%)

negative predictive value (i.e., ability to exclude the presence of coronary atherosclerosis) and high diagnostic sensitivity for identifying stenosis in the proximal and mid segments (>1.5 mm in diameter) of the main coronary arteries [9–15]. Despite the potential of CCTA in the evaluation of patients, great concern has been expressed regarding the possibility that CCTA will result in increased testing or layering of tests [16].

Since there is little data regarding the impact of CCTA on subsequent downstream test we assessed the effect of CCTA on utilization of other non invasive tests in a "real world setting", a 17 member cardiology group (Cardiovascular Medical Group of Southern California, Beverly Hills California). We conducted a retrospective review of practice volume (new patient and office consultations, follow-up office visits, hospital admissions and consultations, follow-up hospital visits), and the number of non-invasive (ECG, TME, SBE, SPEC MPI, CCS, CCTA) and invasive procedures (ICA, PCI) performed annually for the first 2 years in which CCTA was available (2006–2007) and the two prior years (2004–2005).

Methods

Patients and data collection

To determine the number of non-invasive and invasive procedures performed during the period from January 1, 2004 through December 31, 2007, billing codes for non-invasive (CCTA, MPI, SBE, TME) and invasive (ICA, PCI) procedures were identified and used to query the practice management system (Megawest®). Additionally, the practice management system was queried for practice demographics each year (new patient and office consultations, follow-up office visits, hospital admissions and consultations, follow up hospital visits).

Multidetector computed tomography

CCTA became available in the practice in late 2005 with the first full year of operation in 2006. CCTA generally was performed in patients determined to be at intermediate risk by the referring cardiologist and with indications as outlined in the California

Medicare Local Coverage Determination for Cardiac CT [16]. Only patients without contraindication to iodinated contrast agents were tested. The use of CCTA by individual physicians, as the first test compared to MPI-SPEC varied among physicians and over the years with a tendency to broader use and more frequent use as the first test in later years.

Data acquisition was performed using a 64-slice multidetector computed tomography (MDCT) (Light-Speed® VCT 64-Slice scanner, GE Medical systems). To avoid motion artifacts caused by elevated heart rate, prior to the procedure patients routinely received 50–100 mg metoprolol orally several hours prior to the procedure, followed by up to 100 mg of intravenous metoprolol as needed to achieve HR <60 bpm. All patients had oral hydration before and after the study. Nitroglycerine spray (0.4 mcg) was administered just before the test. After a noncontrast scan using 2.5 mm thick slices to measure the CCS, 60–100 mg intravenous contrast (Visipaque® (iodixanol) or Omnipaque® (iohexol), GE Healthcare) was infused. Triggered by aortic contrast aorta opacification, CT acquisition for CCTA was performed during a breath-hold. Detector collimation was set at 64 channels × 0.625 mm/slice, gantry rotation speed at 375 ms per rotation, and tube voltage 100–140 kV (depending on the patient's body weight) at a current of 350–750 mA with retrospective helical reconstruction and dose modulation or prospective scanning. Image data sets were analyzed using multiplanar reconstruction, volume rendering, and vessel analysis software packages (AW 4.3 and 4.4, GE Medical Systems); this technology allowed reconstructed slice thickness of approximately 0.6 mm.

The CCS was assessed using semi-atomically (SmartScore 3, GE Medical Systems. A calcified lesion was defined as the presence of ≥1 lesion of ≥3 pixels with a peak Hounsfield unit (HU) density of >130. The Agaston score for determination of the CCS was calculated as: area of calcification × peak density [17].

All CCTA angiograms were evaluated by readers meeting level III experience as defined by ACC/AHA criteria [18] and reported according to SCCT criteria [19]. Study quality was determined on the basis of motion artifact and contrast-to-noise ratio. After qualitative assessment, a lesion was evaluated as normal, 0–25, 26–50, 51–75, >75% and absence of contrast opacification of the coronary artery lumen

was considered to represent total coronary occlusion or subtotal occlusion. Non calcified plaque burden was evaluated as none, mild, moderate or severe and the CCS score was reported for each CCTA. The attending Cardiologist independently decided on downstream testing or testing prior to CCTA.

Invasive coronary angiography

ICA was performed by the Judkins' technique. Standard projections were obtained after intracoronary injection of Visipaque® (iodixanol) or Omnipaque® (iohexol) (GE Healthcare). Decisions for percutaneous coronary intervention were made independently by the interventional cardiologist who reviewed all non invasive testing information, the clinical history before proceeding with PCI.

Data analysis

Annual utilization and practice demographics were summarized in an Excel (Microsoft) spreadsheet. For each parameter, a linear regression analysis was performed to assess the statistical significance of the trend over the 4-year period. Bar charts were constructed to graphically represent utilization of both non-invasive and invasive diagnostic procedures for all 4 years.

Results

Annual practice demographics and procedure utilization rates for the period from 2004 to 2007 are summarized in Table 1, and annual utilization of non-invasive and invasive procedures is depicted in Figs. 1 and 2. During the study period, there were no significant changes in indicators of practice volume including office and hospital patient visits admissions and consultations. Also the number of ECGs another measure of general office activity did not change significantly.

During 2006, the first full year of availability, 1,405 CCTA studies were performed; in the second full year, the number of CCTA studies decreased (from 1,405 to 945). Increased utilization of CCTA was associated with a significant 49% decrease in TMT exercise tests (471 in 2004 vs. 241 in 2007, $P = 0.023$) and significant 19% reduction in SPEC

Table 1 Utilization data, 2004–2007

	2004	2005	2006	2007	*P*-value
Practice demographics					
New patients and office consults	3,998	3,780	3,665	3,665	NS
Follow-up office visits	27,857	25,837	26,384	27,401	NS
Hospital admissions and consultations	3,416	2,878	2,773	3,468	NS
Hospital visits	18,087	15,517	13,593	16,200	NS
Non-invasive procedures					
ECG	15,679	13,358	13,903	14,670	NS
TME	471	401	272	241	0.023
SBE	1,116	952	1,146	1,223	NS
SPECT	3,223	3,139	2,810	2,614	0.021
Calcium score	0	30	715	1132	0.045
CCTA	0	74	1405	945	N/A
Invasive procedures					
ICA	2,083	1,848	1,589	1,150	0.012
PCI	405	457	425	326	NS
Stents	352	379	386	275	NS
PTCA	53	78	39	51	NS
PCI/ICA (%)	19%	25%	27%	28%	0.008

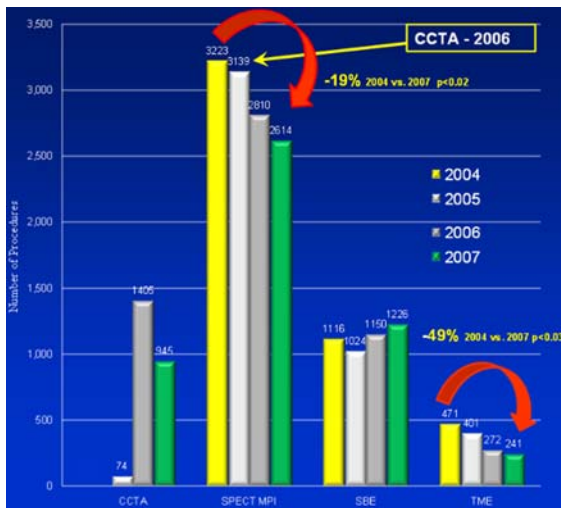*N/A* not applicable, *NS* not significant

Fig. 1 Utilization of non-invasive diagnostic procedures from 2004 to 2007. Changes in utilization of cardiac testing from 2004 to 2007. CCTA first full year of implementation was in 2006. SPECT MPI utilization fell 19% and TME fell 49% between the years 2004 and 2007

Fig. 2 Utilization of invasive procedures from 2004 to 2007. The number of invasive coronary angiogram fell 45% between the years 2004 and 2007 following the implementation of CCTA in the year 2006. However, the incidence of PCI remained stable

MPI (3,223 in 2004 vs. 2,614 in 2007, $P = 0.021$), but had no significant impact on SBE with a non significant trend upwards.

Over this time, increased utilization of CCTA was associated with a significant 45% decrease in ICA procedures (2,083 in 2004 vs. 1,150 in 2007,

$P < 0.012$) but had no significant impact on PCI incidence (405 in 2004 vs. 326 in 2007). Implementations of CCTA in the office also was associated with a significant 53% increase in the proportion of ICA undergoing PCI (19% in 2004 vs. 29% in 2007 $P = 0.008$).

Overall procedures, including CCTA, decreased. Comparing all procedures from 2004 to 2007, there were 230 less TMT, 609 less SPECT scans, 933 less

ICA and 79 less PCI, offset by an increase of 945 CTA. Thus 1,851 less procedures were offset by an increase in 945 CTA procedures. The overall revenue of the practice when considering the addition of CCTA and reduction in other non-invasive testing was within 10% each year and although lower in later years changes did not reach statistical significance.

Discussion

Once 64-slice MDCT was implemented, CCTA was rapidly adopted within the practice. During the first full year of availability, 1,405 CCTA procedures were performed. During the second year, fewer CCTA procedures were performed as other community CTs became available and as cardiologists became familiar with indications and utility of CCS testing. Increased reliance on CCS might have played a role in a lower second year volume of CCTA and going forward physicians focused on measurable plaque burden and altered their medical approach. We have previously reported in this cohort that the findings of calcified and non-calcified plaque on Cardiac CT lead to a change in medical strategy for CAD with aggressive reduction of LDLs, this despite near normal LDL values at baseline [20, 21].

The adoption of CCTA was also associated with a significant reduction in SPECT MPI, suggesting that CCTA replaced SPECT MPI to some extent. The reduction in SPECT MPI may be explained by a shift in diagnostic paradigm in which CCTA was performed as a first line test instead of SPECT MPI for evaluation of patients with intermediate pretest risk of CAD, consistent with current appropriateness criteria [8, 18]. Further, the strong negative predictability of CCTA would support a decreased need for downstream SPECT MPI [10, 22]. Also, the number of stress echocardiograms performed in the last 2 years of the study is greater than the first 2 years, most likely reflecting some substitution of SPECT MPI to stress echocardiography, perhaps due to the desire to avoid a second test utilization radiation.

The reduced number of patients referred for invasive coronary angiography and SPECT MPI was partially offset by the number of patients getting CCTA, Calcium scores. However, this resulted in a substitution of very high cost invasive coronary angiography by lower cost office based testing. Since

diagnostic cardiac catheterization is associated with severe adverse events in 0.7–1.5% of patients and associated deaths in 0.07% the avoidance of unnecessary cardiac catheterization in subjects at relatively low risk of cardiac events is clinically significant and with substantial cost savings [23–25].

Others have predicted or have estimated that the potential reductions in myocardial perfusion imaging and invasive coronary angiography might be considerable in the setting of the utilization of CCTA as the first test for the intermediate risk patient or the patient with acute coronary syndrome [26–29]. Such estimates suggest reductions in excess of 74%. [26]. However, this is the first report in a "real world" uncontrolled setting which documents dramatic reductions in ICA and simultaneous reduced downstream testing of SPECT MPI and TME. Even more appropriate and cost efficient testing might be achievable by only considering patients for provocative testing who have failed medical management and or have suspicious narrowing's on CCTA that require invasive coronary for clarification or intervention.

In this practice, implementation of CCTA was associated with a significant 45% decrease in ICA over the study period (from 2,083 procedures in 2004 to 1,150 in 2007, $P = 0.012$) but had no significant impact on the number of percutaneous revascularization procedures performed. As a result, implementation of CCTA was associated with a significant 53% increase ($P = 0.008$) in the proportion of ICA studies showing significant angiographic narrowing's resulting in the need for percutaneous coronary intervention. This implies that there was more accurate detection of disease that ultimately underwent PCI with fewer patients with normal or non occlusive disease undergoing invasive coronary angiography. Following publication of the COURAGE trial in the spring of 2007 [30] this practice experienced a trend toward reduced incidence of PCI (425 in 2006 vs. 326 in 2007) which did not achieve statistical significance. Further evaluation will need to assess utilization rates over the next few years to determine whether there is a significant lasting change in the intervention strategy and resulting impact on ICA and PCI utilization. Finally, this study performed in a private practice cardiology group, parallels a university medical center study which showed a 30% decrease in non-invasive imaging after introduction of CCTA [31]. However, in that study there was a

reported growth of the invasive angiography practice and also decisions may have been controlled by multiple individuals in an academic setting thus confounding the ability to implement and measure an opportunity to reduce the incidence of invasive angiography.

The limitations of our study need consideration: (1) The trends in noninvasive and invasive procedures reported in this study should be viewed with some caution, given the short observation period (2 years before and 2 years after installation of the 64-slice MDCT) and the potential confounding factors of an uncontrolled retrospective study in the setting of concerns about late stent stenosis [32] improved medical management [33, 34] and modest trends towards general reduction in both invasive angiography and PCI in similar practices of approximately 10% (MedAxiom, Neptune Beach Florida-private communication). The utilization of angiography is dynamic and under many influences and therefore CCTA may not solely account for the reduction found in this study. (2) The effects of availability of the calcium score on downstream testing independent of CCTA cannot be determined from this study. (However, identification of non calcified plaque found on CCTA enhanced lipid management [20]). (3) The findings of a normal or non occlusive CCTA may have lead to fewer MPI-SPECT testing and invasive coronary angiography downstream over the entire 4 years once significant occlusive CAD was excluded. Thus, the ability to analyze each year effects sequential is impaired.

Conclusions

Despite these limitations, the dramatic reduction in ICA observed obviates the fear that the anatomic knowledge of asymptomatic coronary narrowing's would lead to increased invasive angiography or more interventions. To the contrary, the introduction of non-invasive CT angiography was associated with a 45% decrease in invasive coronary angiography particularly among those not requiring PCI. In this "real world" uncontrolled setting there was also a decrease (19%) in nuclear perfusion exams and the opportunity for even greater reductions in non-invasive testing. Finally in view of demonstrated reduction of reduction exposure of 90% [35], CCTA

with its strong negative predictability, simultaneous capacity not to miss serious disease and ability to discern those who might benefit from medical versus an invasive strategy is an attractive choice as the first test for the intermediate risk patient. Prospective multicenter control trials are warranted to evaluate the opportunity to reduce the rate of overall cardiac imaging procedures, to redefine the utilization and choice of non invasive testing, to find the best pathway to avoid redundant layering of testing and to be sure the right patient gets referred for invasive coronary angiography.

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