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Coronary Computed Tomography Versus Radionuclide Myocardial Perfusion Imaging in Chest Pain Patients Admitted to Telemetry: A Randomized, Controlled Trial

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Abstract

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BACKGROUND—Coronary computed tomography angiography plays an expanding role managing symptomatic patients with suspected coronary artery disease. Prospective intermediate-term outcomes are lacking.

OBJECTIVE—To compare coronary CT angiography with conventional non-invasive testing.

DESIGN—Randomized, controlled comparative effectiveness trial.

SETTING—Telemetry-monitored wards of one inner-city medical center.

PATIENTS—400 acute chest pain patients (mean age 57); 63% women; 54% Hispanic, 37% African-American; low socioeconomic status.

INTERVENTION—Coronary CT angiography (CT) or radionuclide stress myocardial perfusion imaging (MPI).

MEASUREMENTS—The primary outcome was cardiac catheterization not leading to revascularization within one year. Secondary outcomes included length of stay, resource utilization and patient experience. Safety outcomes included death, major cardiovascular events and radiation exposure.

RESULTS—30(15%) CT patients and 32(16%) MPI patients underwent cardiac catheterization within one year, of which 15(7.5%) and 20(10%), respectively, were not revascularized (-2.5% difference, 95%CI −8.6%–+3.5%; hazard ratio 0.77, 95%CI 0.40–1.49, p=0.44). Median length of stay was 28.9 hours for CT and 30.4 hours for MPI (p=0.057). Median follow-up was 40.4 months. For CT and MPI, the incidences of death (0.5% vs 3%, p=0.12), non-fatal cardiovascular events (4.5% vs 4.5%), re-hospitalization (43% vs 49%), emergency visit (63% vs 58%) and outpatient cardiology visit (23% vs 21%) were not different. Long-term, all-cause radiation was lower for CT (24 vs 29 milliSieverts, p<0.001). More CT patients graded their experience favorably (p=0.001) and would undergo the exam again (p=0.003).

LIMITATIONS—Single site study; primary outcome dependent on clinical management decisions.

CONCLUSIONS—There were no significant differences between CT and MPI in outcomes or resource utilization over 40 months. CT had lower associated radiation and was more positively-experienced than MPI.

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INTRODUCTION

Cardiovascular disease, including coronary heart disease, is the leading cause of mortality worldwide (1–2). Chest pain with clinical suspicion of coronary artery disease is among the most frequent reasons for urgent care and leads to several million Emergency Department visits and hospitalizations yearly (3). Clinical evaluation is often supplemented with non-invasive cardiac imaging despite the lack of evidence for outcomes benefits and a low diagnostic yield (4). The choice of modality is a focus area for comparative effectiveness research (5).

Coronary computed tomography angiography (CT), a relatively new diagnostic modality, has become a dominant means for evaluating chest pain patients and has impressive diagnostic (6–8) and prognostic (9–11) power. Registry data suggests that CT appropriately selects patients for cardiac catheterization and coronary revascularization (12–13). Randomized trials conducted in low-risk Emergency Department chest pain patients demonstrate that CT is more time-efficient and inexpensive than standard triage protocols which usually involve electrocardiography-, echocardiography- or radionuclide scintigraphy stress testing (14–17).

Concerns regarding CT remain, including false positive results (6,8) leading to invasive management, high radiation dose (17–18), increased downstream resource utilization (17, 19–20) and the relatively low risk profile and short duration of follow-up in the published prospective studies (14–17). Women and ethnic minorities are underrepresented in the existing literature (21–23). It is widely appreciated that results of studies performed in men and in homogeneous ethnic populations require validation before widespread clinical application.

We set out to study coronary CT in an ethnically diverse, inner-city, majority women population of intermediate risk chest pain patients admitted to telemetry with a planned intermediate term of follow-up. As a comparison, we used radionuclide stress myocardial perfusion imaging (MPI), our institution’s default imaging modality and perhaps the best-studied non-invasive exam for detecting severe coronary heart disease (24). We hypothesized that CT would provide superior selection of patients for invasive management and decrease length of stay without compromise of patient safety, as compared to MPI.

METHODS

Design Overview

PROSPECT (*Prospective Randomized Outcome trial comparing radionuclide Stress myocardial Perfusion imaging and ECG-gated coronary CT angiography*) was a randomized, controlled comparative effectiveness trial comparing initial CT with MPI in chest pain patients admitted to telemetry at a single center who clinically required non-invasive imaging to determine management and met pre-defined intermediate risk criteria. Patients were clinically assigned to any one of a group of approximately 30 managing physicians, most of which were hospitalists on the physician assistant telemetry service. Assessors of the primary outcome were blinded to trial arm; patients, imagers, coronary angiographers and managing clinicians were not blinded. The complete trial design and rationale has been previously described (25). The study was approved by our institutional review board, HIPAA compliant, overseen by an independent Data and Safety Monitoring Board and registered at ClinicalTrials.gov (NCT00705458).

Setting and Participants

Patients were identified by screening telemetry admissions for chest pain from July 2008 through March 2012 (when the recruitment goal was reached) at our inner-city academic medical center. Patients without known coronary artery disease, as determined by patient and physician interview and review of medical records, were potentially eligible if there was no acute myocardial infarction/ ischemia on ECG or serum cardiac biomarkers. At least one intermediate risk criterion for short-term death or myocardial infarction derived from an unstable angina management guideline (26) was required: (1) pain for >20 minutes, (2) pain onset at exertion within the previous two weeks, (3) age >70 years, (4) sub-threshold elevation of serum troponin-T, or (5) non-specific ST-segment or T-wave changes on presentation ECG. Exclusion criteria included: prior coronary CT, MPI or cardiac catheterization within 6 months and contraindications to coronary CT including renal insufficiency, active asthma, poor venous access, intravenous contrast allergy or other serious allergy and dysrhythmia precluding cardiac gating. All patients provided written, informed consent (English and Spanish forms provided). No patients were excluded due to language as a telephone interpretation service was used. Patients were not compensated for participation.

Randomization and Interventions

Blocked, 1:1 randomization was performed by an experienced biostatistician (KDF) using SAS software-generated codes. Codes were concealed in sequentially-numbered, sealed, opaque envelopes. Trial coordination staff enrolled participants and assigned the initial imaging intervention which was then formally ordered by the managing hospitalist. Imaging was performed immediately and interpreted with complete access to clinical information and without blinding. After imaging, clinical care decisions were made by the managing physicians.

Coronary computed tomography angiography (CT) was performed on conventional 64-detector-row scanners with heart rate control by intravenous metoprolol tartrate, when needed. Coronary calcium was scored. CT angiography was retrospectively gated with ECG-triggered current modulation or prospectively gated, depending on availability and heart rate. Patients received intravenous iodixanol-320 followed by a saline chaser at 5 ml/second. Scanner voltage and current, contrast injection protocol and pre-medication with sublingual nitroglycerin were tailored by the cardiothoracic radiologist. One of multiple experienced, subspecialty fellowship trained cardiothoracic radiologists interpreted the studies using multiplanar, curved planar and maximum intensity projection reconstructions.

Radionuclide stress myocardial perfusion imaging (MPI) was generally performed using one-day dual-isotope (201-Tl rest / 99m-Tc-sestamibi stress) or 99m-Tc-sestamibi rest/stress imaging. The default stressor was treadmill exercise per the Bruce protocol. Patients unable to exercise received intravenous adenosine or regadenoson with or without low-level exercise. The exact administered dose, radiotracers and mode of stress were tailored by the nuclear cardiologist. Single photon emission computed tomography, gated and attenuation-corrected images were generated. One of multiple experienced, certified, nuclear cardiologists or nuclear medicine physicians interpreted the studies using standard quantification algorithms.

Outcomes and Follow-up

The primary outcome was catheterization not leading to percutaneous or surgical revascularization within one year. The primary goal of non-invasive coronary imaging is to select patients who may benefit from revascularization and to obviate cardiac catheterization in the remaining patients. Although debate rages regarding the appropriate use of coronary revascularization, catheterization that does not lead to intervention confers limited incremental value and entails risk. This outcome was measured up to one year as non-invasive imaging should inform the decision to perform catheterization for a significant period of time and there may be patient-related reasons for delay of revascularization. Since the decision to revascularize is multifactorial, a subgroup analysis was performed for patients with significantly abnormal initial non-invasive imaging (at least one ≥70% stenosis or ≥50% left main stenosis on CT; global interpretation of ischemia or probable ischemia on MPI). More detailed description of imaging results is deferred as our primary outcomes were clinical rather than imaging findings.

Length of hospital stay was calculated from randomization to discharge for all patients. Safety outcomes included complications from imaging and revascularization, post-test renal dysfunction, all-cause mortality and non-fatal major adverse cardiovascular events (myocardial infarction, cardiac arrest and cerebrovascular accident). Subsequent resource utilization (hospitalization, Emergency Department visit, cardiac and non-cardiac imaging and changes in pharmacotherapy) was recorded. Patients' subjective experiences of imaging were assessed on a 10-point Likert-type scale (1 is best), by comparison to other diagnostic testing on an ordinal scale, by willingness to undergo the procedure again on an ordinal scale and by recorded complaints immediately after imaging. The persistence of chest pain was assessed at telephone follow-up. Radiation from CT was estimated using the dose-length product and a conversion factor of .017 microSieverts / milliGray * cm. Radiation from MPI was estimated using recorded standard dose of isotope and a public calculator (27). Doses from subsequent imaging and catheterization were determined with a public calculator (28).

Outcomes were assessed by review of electronic medical records (spanning numerous health system sites) and telephone questionnaires at 6 and 12 months after discharge and at study completion (December 2013). Patients unreachable by telephone and without institutional electronic records were followed-up by contacting providers' offices. When patients, physicians or records indicated that cardiac care was rendered outside our health system, records were requested for review.

Statistical Analysis

The study had 84% power to detect a reduction of catheterization not leading to revascularization from 11% to 3% with a sample size of 200 per arm at α=0.05 (25). All randomized patients were included in the analysis in the trial arm to which they randomized. The primary outcome was assessed by a Cox proportional hazards model (PROC PHREG in SAS version 9.2) with the proportional hazards assumption tested by log-rank and inspection of survival curves. A post-hoc exploratory analysis for the primary outcome was performed in patients with severely abnormal non-invasive testing. Safety outcome and resource utilization analyses included all patients over the complete follow-up period. Proportions were compared using Fisher's exact tests (29) and confidence intervals were computed for differences (30). The Mann-Whitney U test for independent samples was used for non-parametric data using SPSS version 20. All tests were two-tailed and performed at α=0.05.

Role of the Funding Source

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RESULTS

Study Patients

Of 400 patients, 200 were randomly assigned to each arm (Fig. 1). The mean age was 57 years, 251 (63%) participants were women and 379 (95%) were ethnic minorities (Table 1). The randomized test was completed in similar proportions of patients for CT (94%) and MPI (95%). Follow-up of at least one year for the primary outcome and adverse events was complete in 381 (95%). The 19 patients lost to follow-up had similar demographics (mean age 56; 9 women).

Outcomes

30 (15%) CT patients and 32 (16%) MPI patients underwent one or more cardiac catheterizations within one year (p=0.89), (Table 2). Of these, 15 CT and 20 MPI patients were not revascularized (unadjusted hazard ratio 0.77 [95% confidence interval = 0.40 −1.49], p=0.44). The median times to catheterization and revascularization were 3.5 (inter-quartile range [IQR] 2 – 28.5) and 2 (IQR 1.5 – 3.5) days, respectively, for CT and 2 (IQR 1 – 5) and 1.5 (IQR 1 – 4) days, respectively, for MPI. In the exploratory subgroup of patients with significantly abnormal CT or MPI, 5/20 (25%) and 16/31 (52%) had catheterization that did not lead to revascularization, respectively (absolute difference −27%, 95% confidence interval = -50% to +3.9%, p=0.083). The median lengths of stay in the CT and MPI arms were 28.9 (IQR 11.0 – 48.4) hours and 30.4 (IQR 23.9 – 51.3) hours, respectively (p=0.057). No patients in either arm had post-test renal dysfunction. The median follow-up for safety outcomes was 41.7 (IQR 28.6 – 51.0) and 39.0 (IQR 28.3 – 51.6) months for CT and MPI, respectively. One CT patient and 6 MPI patients died during follow-up (p=0.122) at a median of 24.5 months after recruitment. 9 CT patients and 9 MPI patients had non-fatal major adverse cardiovascular events.

Clinical and imaging resource utilization is shown in Table 3.

Three CT patients received non-coronary diagnoses that led to surgery (one ascending aortic aneurysm, one atrial septal defect and one adrenal pheochromocytoma). Seven CT patients had extra-cardiac diagnoses that explained their symptoms (4 acute pulmonary emboli, 3 pneumonias). MPI led to no non-coronary surgical diagnoses or extra-cardiac explanations of symptoms.

Radiation Doses

CT and MPI dose was available for 184/187 (98%) and 189/189 (100%) patients who received their randomized exam, respectively, (Table 4). The median effective dose was significantly lower for CT [9.6 (IQR 6.2 – 23) milliSieverts] than for MPI [27 (IQR 19 – 27) milliSieverts], (p<0.001). Marked dose reduction trends were noted in both arms over the study period. Through the end of the follow-up period, both CT and MPI patients underwent a median of 3 (IQR 1 – 9) non-cardiac studies involving radiation. The estimated median radiation dose was 2 mSv (IQR 0.003 – 16) for CT and 2 mSv (IQR 0.004 – 17) for MPI.

Subjective patient experience

Subjective patient experience of the imaging exam was assessed in all patients who underwent their randomly assigned study, with complete data available for 186/187 CT and 188/189 MPI patients. The median exam rating scores out of 10 (1 being highest) were 2 (IQR 1 – 3) and 2 (IQR 1 – 3.5) for CT and MPI, respectively (p=0.149). 28 (14%) CT and 45 (23%) MPI patients rated their test less positively with an ordinal score of 5 (descriptor "OK") or worse (p=0.038). CT patients graded their study more favorably than did MPI patients in comparison to other diagnostic tests (p=0.001) and in willingness to undergo the exam again (p=0.003).

45/186 (24%) CT and 46/188 (24%) MPI patients reported one or more general adverse reactions, most commonly headache, nausea, dizziness and warm feeling. One CT patient and 30 MPI patients complained of chest pain, shortness of breath or palpitations (p<0.001). Three CT patients and no MPI patients complained of rash or pruritus (p=0.25).

177 CT and 180 MPI patients provided information about symptoms at 6 or 12 month telephone interviews. 64 (36%) patients in each arm had continued chest pain, which was the same or worse in 28 CT and 23 MPI patients.

DISCUSSION

This single-center randomized controlled comparative effectiveness trial provides the first direct comparison of CT and MPI in acutely symptomatic, intermediate-risk chest pain patients with intermediate-term follow-up (median 40 months). The present study population – predominately women (63%) and ethnic minorities (95%) of low socioeconomic status and a high incidence of obesity (mean BMI 31) – is understudied and differs from prior randomized trials (14–17). Some studies have compared standard care with early CT (14,17); the present study gave parity to both modalities which were performed at the same place in the treatment algorithm. This study included only patients who clinically required non-invasive imaging unlike the largest Emergency Department CT trials in which many standard care patients received no imaging (16–17).

We found no significant difference between CT and MPI in the primary outcome, cardiac catheterizations not leading to revascularization. The moderate study sample size does limit the ability to detect a small difference between modalities, but the clinical importance of such a difference is uncertain. These data mirror a large retrospective study showing the majority of non-emergent cardiac catheterizations demonstrate no significant disease (31) and suggest that this holds true even for patients pre-screened with currently leading non-invasive imaging. In our exploratory subgroup analysis of patients with significantly abnormal initial imaging, there were non-significantly fewer catheterizations not leading to revascularization in the CT arm (25% vs 52%, p=0.083). The recently published PROMISE trial including 10,000 symptomatic outpatients demonstrates that CT results in a statistically significant, 0.9% reduction in catheterizations showing no obstructive coronary disease as compared to various forms of functional testing (32). The decision to catheterize patients remains dependent on factors other than initial non-invasive imaging, such as clinical presentation, persistence of symptoms, repeated clinical encounters, subsequent testing and clinician and patient preference. These data suggest a small potential benefit of initial CT.

We found no difference between CT and MPI in cardiac catheterizations within one year (15% vs 16%). This differs with research derived from a retrospective review of Medicare claims data (19), a meta-analysis of randomized trials in low risk Emergency Department patients (20) and a large multi-center trial of outpatients (32), all of which showed increased catheterizations after CT. We observed that the time to catheterization was longer for CT than MPI, which is likely a reflection of the desire to avoid potentially nephrotoxic, immediate consecutive administrations of intravenous contrast. We found no significant difference between CT and MPI in percutaneous coronary interventions (4% vs 5.5%) which also differs from the prior studies. Although the reasons for these differences are uncertain, the diverse patient settings (inpatient, Emergency Department, outpatient) could play a role.

We found an increase in coronary artery bypass in the CT versus MPI arm (4% vs 0.5%, p=.068), which is confirmed by a large trial in outpatients showing near doubling of the rate for patients undergoing CT (32). This could be explained by “balanced” ischemia, which is a known limitation of MPI. Alternatively, the increase in coronary bypass in the CT arm could be due to overtreatment since both CT and catheterization demonstrate anatomic stenosis and are more similar to each other than to MPI, a physiological modality. However, if this were the case we would have expected more percutaneous interventions in the CT arm, which we did not observe. Major adverse cardiovascular events were similar between the two groups; similar event rates are also reported in outpatients undergoing CT and functional testing (32). CT led to clinically important non-coronary diagnoses in 10 patients (5%), some of which led to surgery. These would not reasonably have been diagnosed by MPI and represent an advantage of CT.

Length of stay was not meaningfully different between the CT and MPI arms (median 29 vs 30 h), while prior published trials in Emergency Department patients favored CT (14–17). A likely reason for this difference is that patients in the current study were recruited without immediate, dedicated CT availability. In addition, our higher risk patients (with intermediate level criteria for short-term death or myocardial infarction) had a higher incidence of catheterization and revascularization. These interventions were usually performed during the same hospitalization. The speed of an imaging study is highly dependent on local facilities and practice patterns. This limits the generalizability of analysis of length of stay.

Downstream resource utilization including repeat hospitalizations and Emergency Department visits for cardiac and non-cardiac complaints, outpatient cardiologist and primary care visits, non-invasive cardiac imaging and catheterization did not differ between the CT and MPI arms. This is at variance with retrospectively analyzed Medicare claims data (19). New aspirin and statin therapy did not differ significantly between the CT and MPI arms.

Radiation doses for initial imaging were significantly lower for CT than MPI (median 9.6 vs 27 mSv) which decreased but remained highly significant over long-term follow-up when both cardiac and overall imaging was considered (median 24 vs 27 mSv). For comparison purposes, according to an accepted linear extrapolation (28), 10 mSv confers a lifetime risk of fatal cancer induction of 50/100,000 in 60 year old patients. The large reported doses in this study directly reflect the higher radiation Thallium isotope used for imaging most of our patients. Recent trends favor lower dose, sestamibi-only protocols which have been formally adopted at our institution (February, 2011) and elsewhere. Additional recent advances in radiation dose reduction have been achieved with high-efficiency MPI (33) and newer CT scanner technology (34).

Patients rated their non-invasive imaging experience with CT better than with MPI (fewer unfavorable experience ratings), in comparison with other diagnostic tests and greater willingness to undergo the exam again. This correlates with the higher incidence of patient complaints of chest pain, palpitations and shortness of breath with MPI. There was no significant difference between the CT and MPI groups in persistent chest pain; about one third remained symptomatic in each group.

This study has several limitations. Foremost, this was a single center study and institution-specific factors may limit generalizability. However, our majority female, ethnically diverse, low-income population remains understudied. Our sample size is comparable to most prior CT studies and the duration of follow-up is far longer. The current study only included patients who were appropriate candidates for both CT and MPI and did not assess other modalities. Second, the decisions to perform cardiac catheterization and revascularization, the components of our primary outcome, were made clinically without a pre-defined algorithm. The managing physicians were clinically assigned and not blinded. Factors other than initial imaging played a role in treatment decisions, closely resembling real-life practice, which is also not constrained by strict algorithms for management. Third, the identification of clinical events and subsequent resource utilization, including follow-up of incidental findings on CT, is limited to our health system network and follow-up discussions with patients and their physicians. Downstream events at other institutions could be missed as there is no unified system for medical records. This study is underpowered to detect potentially important differences in clinical events and resource utilization. Fourth, major advancements in CT (such as CT-fractional flow reserve (35) and perfusion (36)) and nuclear cardiology (such as positron emission tomography techniques (37), including coronary flow reserve (38)) are continuous and significantly alter the performance characteristics of these modalities over time. Fifth, radiation dose data is based on imaging protocols which have changed over the time of the study and rely on standardized recorded amounts of isotopes. Finally, we observed a greater proportion of patients over age 70 in the CT arm (17% vs 10%), a potential source of bias.

In conclusion, the present study demonstrated no significant difference between initial CT and MPI in catheterization not leading to revascularization, a measure of performance in selecting patients for invasive management. A trend towards more coronary bypass grafting in the CT arm remains of uncertain clinical impact. Length of stay, downstream resource utilization and clinical events also did not differ between the CT and MPI arms in this diverse, inner-city population at intermediate-term follow-up. CT was associated with lower radiation dose and a better patient experience.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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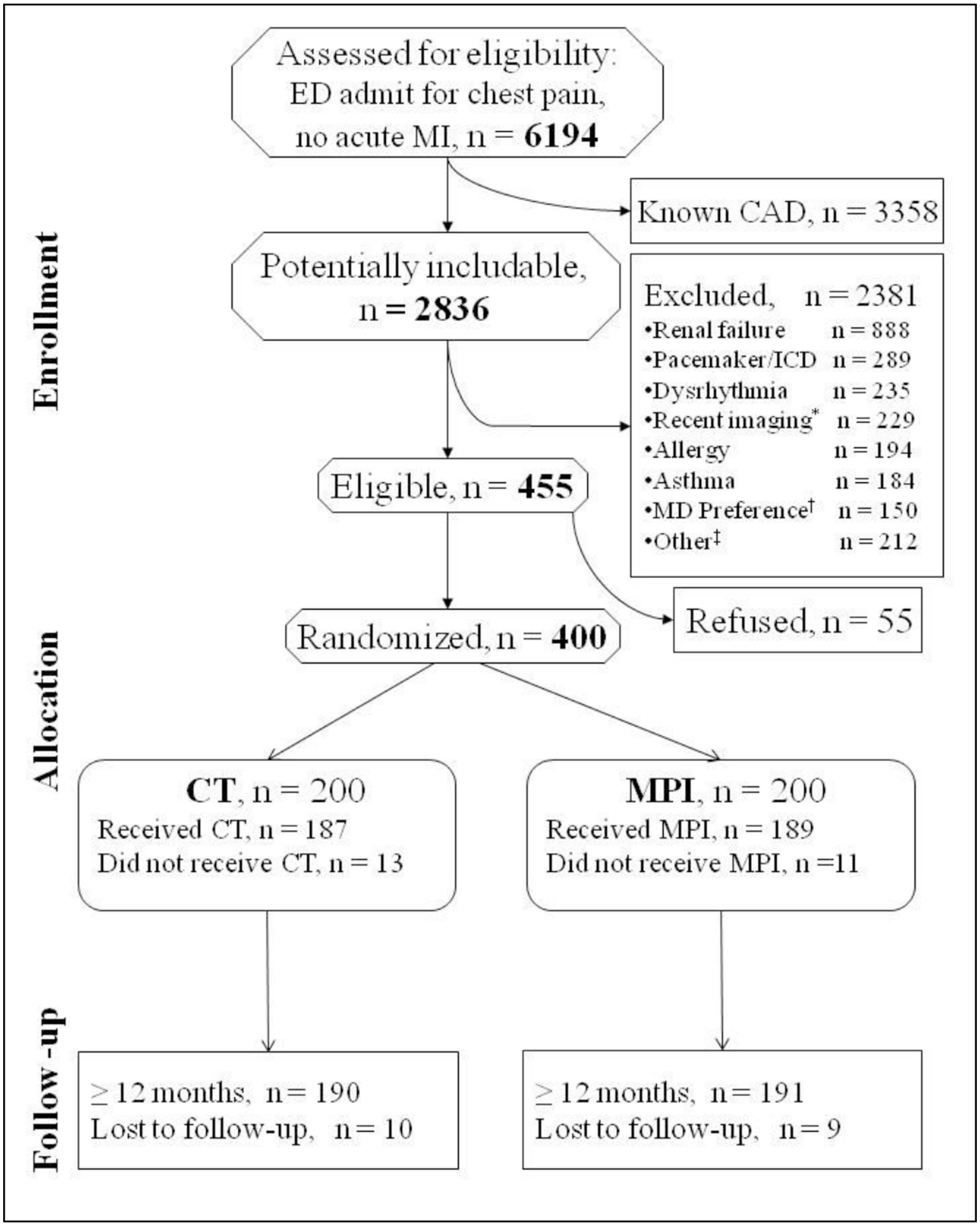

Figure 1.

CONSORT Flow Diagram.

Footnote: CAD, coronary artery disease; CT, coronary computed tomography angiography; ED, emergency department; ICD, implanted cardioverter/defibrillator; MI, myocardial infarction; MPI, radionuclide stress myocardial perfusion imaging.

*Recent imaging means coronary CT, MPI or cardiac catheterization within 6 months

†MD preference means the managing physician had already chosen a non-invasive imaging modality and would not allow the patient to be randomized.

‡Other reasons for exclusion are listed in Supplementary Online Table 1.

CT was not performed in 13 patients because of patient refusal (9), physician decision (1), technical difficulty (1) and safety concerns (2); of these, 7 patients received MPI. MPI was not performed in 11 patients because of patient refusal (6), physician decision (4), and technical difficulty (1); of these, 0 patients received CT. During hospitalization, 6 patients that received initial CT had additional MPI and 4 patients that received initial MPI underwent additional CT. Lost patients could not be contacted by any means including identification and inquiry of any treating physicians. All patients were included in the primary analysis (Cox proportional hazards model).

Table 1

Baseline Characteristics

Characteristic	Total (n=400)	CT (n=200)	MPI (n=200)
Demographics			
Female	251 (62.8)	126 (63.0)	125 (62.5)
Mean Age (SD)	56.6 (11.2) years	56.8 (11.8) years	56.3 (10.5) years
Ethnicity (self-reported)			
Hispanic	213 (53.7)	105 (52.8)	108 (54.6)
African-American	145 (36.5)	78 (39)	67 (34)
Asian	18 (4.5)	7 (4)	11 (5.6)
Caucasian	18 (4.5)	8 (4)	10 (5.1)
Other	3 (0.8)	1 (0.5)	2 (1)
Interpreter used	103 (25.8)	50 (25)	53 (27)
Mean SES Z-score*	−4.2	−4.1	−4.3
Risk Factors			
Mean BMI (SD)	30.6 (6.4) kg/m^2	30.5 (6.2) kg/m^2	30.7 (6.6) kg/m^2
Diabetes mellitus	127 (31.8)	66 (33)	61 (31)
Hypertension	288 (72.0)	141 (70.5)	147 (73.5)
Mean Systolic / Diastolic Blood Pressure (SD)	127 (20) / 75 (13) mmHg	129 (20) / 76 (12) mmHg	126 (20) / 75 (14) mmHg
Dyslipidemia	296 (51.5)	97 (49)	109 (55)
Taking statin	135 (33.8)	61 (31)	74 (37)
Current smoker	59 (15)	33 (17)	26 (13)
1° relative with CAD	148 (37.0)	75 (38)	73 (37)
Taking aspirin	149 (37.5)	77 (39)	72 (36)
No regular exercise	180 (45.0)	98 (49)	82 (41)
Post-menopausal women	174 (43.5)	87 (44)	87 (44)
Presentation / Risk Criteria			
Pain > 20 minutes	248 (62.0)	123 (61.5)	125 (62.5)
New pain on exertion within last 2 weeks	151 (37.8)	72 (36)	79 (40)
ST or T wave abnormality on ECG	113 (28.3)	49 (25)	64 (32)
Age ≥ 70 years	54 (14)	34 (17)	20 (10)
Sub-clinical Troponin elevation	19 (4.8)	8 (4)	11 (5.5)
Diamond-Forrester			
Mean Pre-test probability	37%	36%	37%
Retrosternal pain	278 (69.5)	134 (67.0)	144 (72.0)
Exertional pain	160 (40.0)	77 (39)	83 (42)

Characteristic	Total (n=400)	CT (n=200)	MPI (n=200)
Relieved by rest or nitroglycerin	189 (47.3)	95 (48)	94 (47)
Mean TIMI Score (SD)	1.3 (1.0)	1.3 (1.0)	1.2 (1.0)
Past Medical History			
Gastroesophageal reflux or ulcer disease	182 (45.5)	88 (44)	94 (47)
Chest wall, rib or muscle pain	109 (27.3)	48 (24)	61 (31)
Panic attacks or anxiety disorders	96 (24)	41 (21)	55 (28)

BMI, body mass index; CAD, coronary artery disease; CT, coronary computed tomography angiography; ECG, electrocardiogram; MPI, radionuclide stress myocardial perfusion imaging; SD, standard deviation; SES, socioeconomic status; TIMI, thrombolysis in myocardial infarction

Numbers in parentheses represent percents unless otherwise noted.

*Socioeconomic status score is based on the patient's address zip code (median household income, median value of housing units, percentage of households receiving interest/dividend/rental income, education, percentage of adults who completed college, and percentage of employed individuals in executive/managerial/professional positions) and is normalized to the New York state average.

Table 2

Primary, Secondary and Safety Outcomes

Outcome	CT (%) (n=200)	MPI (%) (n=200)	% Difference* (95% CI)	P
Cardiac catheterization within 1 year	30 (15)	32 (16)	−1.0 (−8.5, 6.5)	0.89
Cardiac catheterization without revascularization within 1 year	15 (7.5)	20 (10)	−2.5 (−8.6, 3.5)	0.41
CABG within 1 year	7 (4)	1 (0.5)	3.0 (−0.3, 6.9)	0.068
PCI within 1 year	8 (4)	11 (5.5)	−1.5 (−6.4, 3.3)	0.64
Median length of stay in hours (IQR)	28.9 (11.0, 48.4)	30.4 (23.9, 51.3)		0.057
Serious complications of imaging	0	0	0 (−2.4, 2.4)	1
Serious complications of revascularization†	3 (2)	1 (0.5)	1.0 (−1.9, 4.2)	0.62
All-cause death	1 (0.5)	6 (3)	−2.5 (−6.3, .7)	0.122
Non-fatal MACE ‡	9 (5)	9 (5)	0 (−4.7, 4.7)	1
Death + MACE §	9 (5)	15 (7.5)	−3.0 (−8.3, 2.2)	0.29

CABG, coronary artery bypass grafting; CI, confidence interval; CT, coronary computed tomography angiography; IQR, inter-quartile range; MACE, major adverse cardiovascular events (consisting of myocardial infarction, stroke and cardiac arrest); MPI, radionuclide stress myocardial perfusion imaging; PCI, percutaneous coronary intervention

*% Difference equals proportion in the MPI arm minus proportion in the CT arm

†Two CT patients had complications after coronary artery bypass grafting (one sternal wound infection and one prolonged mechanical ventilation). One MPI patient had coronary artery dissection during percutaneous intervention. One CT patient had coronary artery perforation during percutaneous intervention for a subsequent acute myocardial infarction.

‡Two MPI patients each had two separate cerebrovascular accidents.

§One CT patient had a non-fatal myocardial infarction and later died.

Table 3

Resource utilization over the complete follow-up period

Resource	CT (%) (n=200)	MPI (%) (n=200)	% Difference* (95% CI)	P
Clinical				
Any re-hospitalization	86 (43)	98 (49)	−6.0 (−16, 4.1)	0.27
Cardiac re-hospitalization	50 (25)	61 (31)	−5.5 (−15, 3.6)	0.26
Any cause ED visit	126 (63.0)	115 (57.5)	5.5 (−4.4, 15)	0.31
Cardiac ED visit	41 (21)	40 (20)	0.5 (−7.7, 8.7)	1
Primary care visit	114 (57.0)	112 (56.0)	1.0 (−9.0, 11)	0.92
Cardiology outpatient visit	46 (23)	42 (21)	2.0 (−6.5, 10)	0.72
Pharmacotherapy				
New aspirin Rx	79 (40)	68 (34)	5.5 (−4.3, 15)	0.30
New statin Rx	50 (25)	36 (18)	7.0 (−1.4, 15)	0.113
Increased statin dose	6 (3)	6 (3)	0 (−4.1, 4.1)	1
Imaging				
Subsequent CT	2 (1)	5 (3)	−1.5 (−5.2, 1.8)	0.45
Subsequent MPI	30 (15)	26 (13)	2.0 (−5.2, 9.2)	0.67
Subsequent SE	13 (6.5)	14 (7)	−0.5 (−6.0, 5.0)	1
Subsequent catheterization†	36 (18)	38 (19)	1.0 (−7.0, 9.0)	0.90
Subsequent catheterization with PCI†	9 (5)	14 (7.0)	−2.5 (−7.7, 2.6)	0.39

CI, confidence interval; CT, coronary computed tomography angiography; ED, emergency department; MPI, radionuclide stress myocardial perfusion imaging; PCI, percutaneous coronary intervention; Rx, prescription; SE, stress echocardiography

*% Difference equals proportion in the MPI arm minus proportion in the CT arm

†Figures differ from Table 2 and the text which report catheterizations within one year.

Table 4

Estimated Radiation Exposure in milliSieverts

Measurement	CT (IQR)	MPI (IQR)	P
Initial assigned non-invasive imaging	9.6 (6.2 – 23) [n=184]	27 (19 – 27) [n=189]	<0.001
Cardiac imaging over one year	12 (6.4 – 26) [n=200]	27 (19 – 27) [n=200]	<0.001
Cardiac imaging over complete follow-up	13 (6.9 –27) [n=200]	27 (19 – 27) [n=200]	<0.001
Non-cardiac imaging studies over complete follow-up	2.0 (.003 – 16) [n=200]	2.0 (.004 – 17) [n=200]	0.91
All radiation over complete follow-up	24 (8.7 – 39) [n=200]	29 (27 – 48) [n=200]	<0.001

CT, coronary computed tomography angiography; IQR, inter-quartile range; MPI, radionuclide stress myocardial perfusion imaging