



**Economic Model of Coronary Computed
Tomographic Angiography for Detection of
Coronary Artery Disease**

Overview & Draft Findings

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CCTA Model: Overview

- 2 microsimulation models developed for separate uses of CCTA (64-slice or better technology):
 1. CCTA in ED triage for patients with acute chest pain of unknown origin and low-to-intermediate risk of acute myocardial infarction or unstable angina
 2. CCTA as outpatient screening tool for coronary artery disease (CAD) in low-to-intermediate risk population presenting with stable chest pain
- Costs and outcomes estimated for (a) diagnostic timeframe only (both settings) and (b) on lifetime basis (outpatient model only)

Model Considerations

- Incidental findings:
 - Lack of data on (a) downstream risk of clinically significant findings and (b) benefits of early detection; costs and effects of incidental findings not explicitly modeled
 - Occurrence of pulmonary nodules likely to require follow-up (>4 mm) estimated based on:
 - Gender/age-specific nodule incidence (CISNET lung cancer policy model)
 - Follow-up recommendations (Fleischner Society)
- Radiation exposure:
 - Lack of data or consensus on likelihood and pattern of CCTA-attributable radiation-induced cancer; long-term consequences of radiation exposure not explicitly modeled
 - For each strategy in outpatient model, number exposed to *any* radiation during diagnostic testing reported

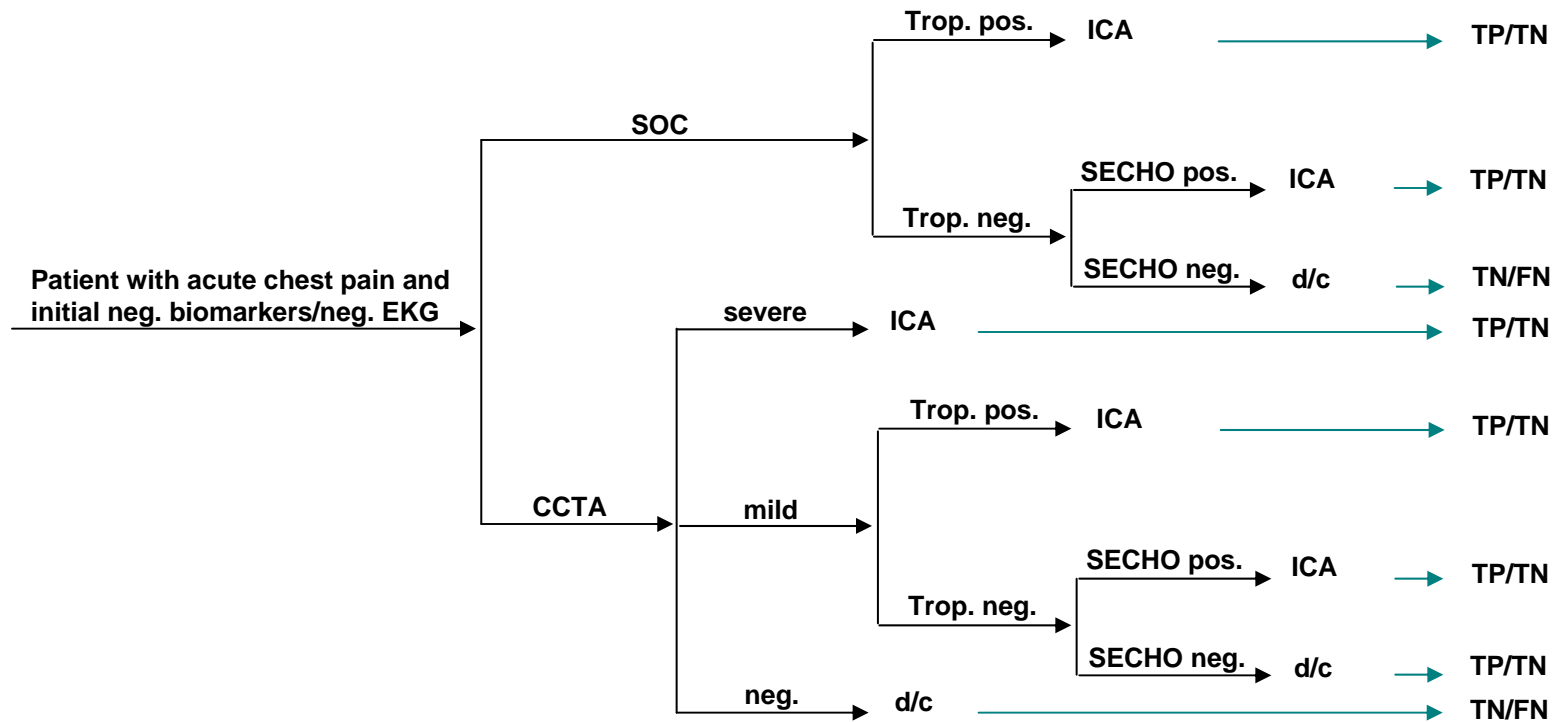
ED Model: Framework

- Target population: 55 yo males presenting with acute chest pain, no significant EKG changes, negative cardiac enzymes
- Strategies:
 1. AHA/ACC standard triage care:
 - Serial enzymes and stress testing (assumed via stress echocardiogram)
 2. CCTA integrated into standard care

ED Model: Framework


- Data sources:
 - CCTA accuracy data: published literature
 - Clinical data: published literature
 - Cost data: Medicare reimbursement rates, other sources
- Key outcomes (diagnostic timeframe only):
 - Diagnostic accuracy (true positive, true negative, false negative)
 - Number referred for invasive angiography (+ and -)
 - Total cost for diagnostic phase
 - Intermediate outcome: cost/false-negative averted

ED Model: Pathways



Notes: severe: stenosis $\geq 70\%$ in vessels or $\geq 50\%$ in left main artery, mild: stenosis $< 70\%$ in vessels or $< 50\%$ in left main artery, SOC: standard of care; CCTA: coronary computed tomographic angiography; Trop.: troponin; ICA: invasive angiography; SECHO: stress echocardiogram

ED Model: Input Parameters

Variable	Base Case Estimate
Initial distribution of disease in ED*	
Non-ST elevation MI	3%
Unstable angina	7%
Stable angina	2%
Non-cardiac chest pain	88%
 12% cardiac-related pain but 27% underlying CAD	
64-slice CT angiography characteristics**	
Probability of classifying severe coronary stenosis as:	
Severe	0.92
Mild	0.07
Normal	0.01
Probability of classifying mild coronary stenosis as:	
Severe	0.21
Mild	0.72
Normal	0.07
Probability of classifying normal coronaries as:	
Severe	0.00
Mild	0.02
Normal	0.98

7 *Zalenski 1997: Arch Intern Med, Sallach 2004: Am J Cardiol, **Shabestari 2008: Am J Cardiol



ED Model: Results

Outcomes (per 1,000)	SOC	CCTA + SOC
True positive	219	264
True negative	733	733
False negative	48	3
Referred for ICA	472	406
ICA negative results	253	149
ICA related deaths	0.05	0.04
Incidental findings w/FU	0	138
Costs (\$ per patient)		
ED/patient	1,594	2,126
Cath lab/patient	576	495
Total/patient	2,170	2,621

Cost per false negative averted: ~\$10,000

gICA: Invasive coronary angiography

Summary: CCTA in the ED

- CCTA:
 -  number of true positives (~15%)
 -  number of unnecessary angiographies (~30%)
- CCTA increases diagnostic costs by \$451/patient
- Reduction in false negatives = ~\$10,000 per false negative averted
- CCTA exposes all patients to radiation (vs. ~45% in SOC pathway from ICA)
- ~14% of CCTAs have incidental findings requiring f/u

Outpatient Model: Framework

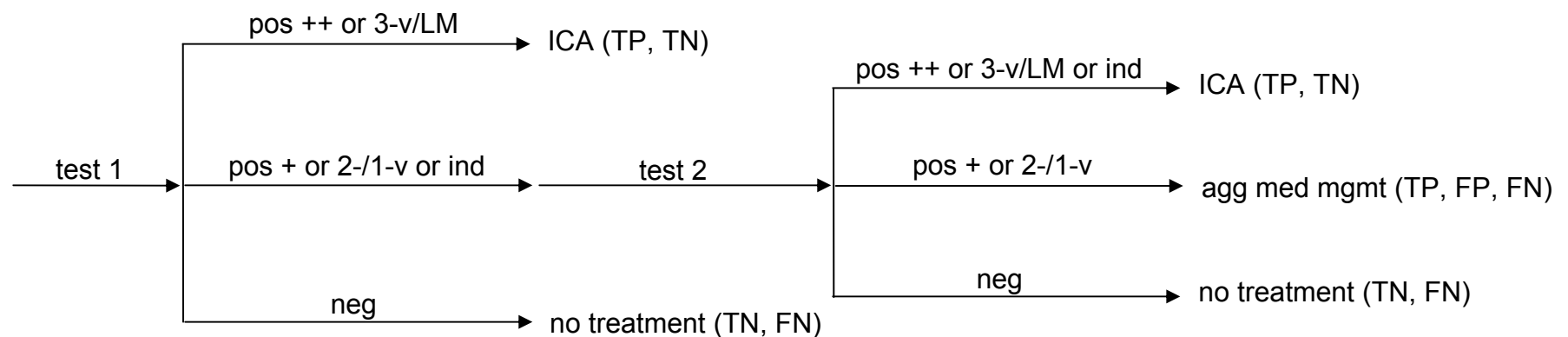
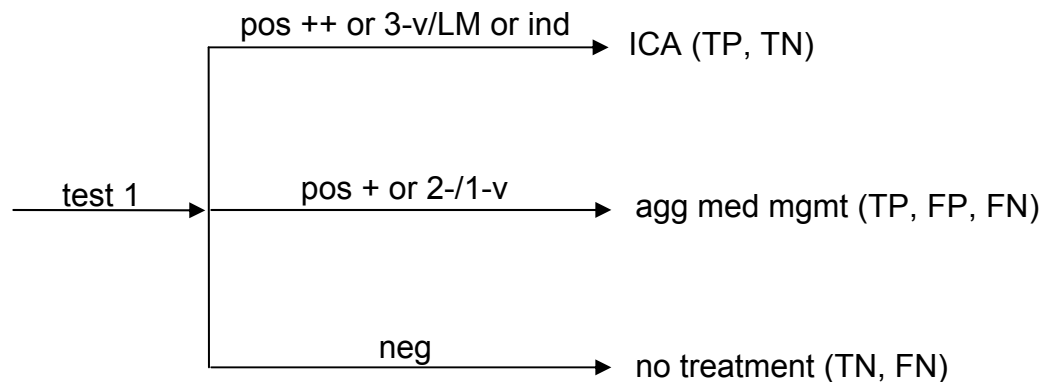
- Target population: 55 yo males with stable chest pain and low to intermediate CAD risk:
 - Underlying CAD prevalence: alternatively 10% and 30%
- Strategies:
 1. Stress-SPECT
 2. Stress-ECHO
 3. CCTA
 4. CCTA followed by stress-SPECT
 5. Stress-SPECT followed by CCTA
 6. CCTA followed by stress-ECHO
 7. Stress-ECHO followed by CCTA

¹⁰ SPECT: Single photon emission computed tomography; ECHO: Echocardiogram

Outpatient Model: Framework

- Data sources:
 - CCTA accuracy data: ICER systematic review
 - Clinical data: published literature
 - Cost data: Medicare reimbursement rates, other sources
- Key outcomes:
 - Diagnostic accuracy (true positive, false positive, true negative, false negative)
 - Number referred for invasive angiography (+ and -)
 - Total cost for diagnostic phase; cost per FN averted
 - Remaining quality-adjusted life expectancy and lifetime costs (both discounted at 3%)

Outpatient Model: Pathways



Notes: pos ++: markedly abnormal test result, pos +: abnormal test result, ind: indeterminate results

Outpatient Model: Input Parameters

Variable	Base case estimate
CCTA*	
Sensitivity	0.97
Specificity	0.87
Indeterminate results*	0.03
Stress ECHO**	
Sensitivity	0.76
Sensitivity for LM or 3v	0.94
Specificity	0.88
Indeterminate results†	0.13
Stress SPECT**	
Sensitivity	0.88
Sensitivity for LM or 3v	0.98
Specificity	0.77
Indeterminate results‡	0.09

*ICER Systematic Review of CCTA diagnostic accuracy

**Garber et al., 1999 Ann Int Med

†Ward et al., 2007 Am J Card

‡Patterson et al., 1995 Circulation

Outpatient Model: Results (per 1,000, 30% CAD prevalence)

	<u>CCTA</u>	<u>SPECT</u>	<u>SECHO</u>	<u>CCTA-> SPECT</u>	<u>SPECT-> CCTA</u>	<u>CCTA-> SECHO</u>	<u>SECHO-> CCTA</u>
True positive	288	273	251	266	268	245	246
False positive	87	145	71	24	29	12	22
True negative	616	558	632	678	675	691	682
False negative	9	24	46	31	29	52	51
Referred for ICA	108	166	200	106	91	120	87
ICA negative results	22	65	95	9	6	13	5
ICA related deaths	0.11	0.17	0.20	0.11	0.09	0.12	0.09
Exposed to radiation	1,000	1,000	200	1,000	1,000	1,000	437
Incidental findings requiring f/u	138	0	0	138	57	138	48
Total costs per patient [excluding FU]	867	967	544	1,110	1,177	977	663

Outpatient Model: Lifetime Extrapolation & Quality of Life

- Survival:
 - Function of:
 - US lifetables stratified by age and gender
 - Number of diseased vessels as observed in the COURAGE trial* (factor 1.4 for 1-2 vessels, 2.2 for 3 vessels, 5.8 for LM)
 - CAD-negative patients can subsequently develop CAD and disease can progress
 - Lack of appropriate treatment (PCI or meds for 1-2 vessel disease, PCI and CABG for 3-vessel and LM disease) increases mortality risk by 30%

*Boden et al., 2007 N Engl J Med

Outpatient Model: Lifetime Extrapolation & Quality of Life

- Utilities:

- Utility values vary by CAD-free (0.96), CAD without chest pain (0.88), and CAD with chest pain (0.78)*
- Occluded arteries cause chest pain; treatment relieves chest pain,** resulting in pain-free fraction after 1 year:
 - No treatment: 13%
 - Medical treatment: 58%
 - PCI: 66%
 - CABG: 74%

*Lalonde et al., 1999 Qual Life Res

**Boden 2007; Hoffman 2003 JACC

Outpatient Model: Lifetime Results, 30% CAD Prevalence

Strategies Ordered by Increasing Effectiveness

Strategy	Effectiveness	Costs
CCTA-ECHO	15.146	21,206
SECHO-CCTA	15.151	16,329
CCTA-SPECT	15.154	23,990
SPECT-CTA	15.157	25,446
SECHO	15.167	12,580
SPECT	15.172	21,255
CCTA	15.183	20,284

Incremental Cost-effectiveness Analysis

Strategy	Effect	Incr. Effect	Costs	Incr. costs	C/E	Incr. C/E ¹
SECHO	15.167		12,580		829	
SECHO-CCTA	15.151	-0.016	16,329	3,749	1,078	(Dominated)
CCTA	15.183	0.016	20,284	7,704	1,336	469,529
CCTA-ECHO	15.146	-0.038	21,206	922	1,400	(Dominated)
SPECT	15.172	-0.012	21,255	971	1,401	(Dominated)
CCTA-SPECT	15.154	-0.029	23,990	3,706	1,583	(Dominated)
SPECT-CCTA	15.157	-0.027	25,446	5,162	1,679	(Dominated)

Strategies without Dominated Options

SECHO	15.167		12,580		829	
CCTA	15.183	0.016	20,284	7,704	1,336	469,529

Summary: Outpatient CCTA

- Effectiveness as measured by quality-adjusted life years is very similar across all diagnostic strategies
- SECHO and SECHO-CCTA have lowest lifetime costs
- CCTA alone strategy cost-effectiveness vs. SECHO:
 - \$ per FN averted: ~\$8,700
 - \$ per QALY gained: ~\$470,000
- Reminder: all analyses without harms, benefits, or costs of radiation or incidental findings
 - ~14% of CCTA-based strategies had incidental findings, vs. 0-5% in other strategies
 - Strategies with CCTA or SPECT as first or only test exposed all patients to radiation, vs. 20-40% in patients with SECHO as first or only test

Appendix

Test Cost Estimates

Procedure, CPT code (description)		Total cost (\$)
SECHO	93015 (cardiovascular stress test) 93350 (echo transthoracic)	300
ICA	93508 (cath placement, angiography) 93543 (injection for heart x-rays) 93545 (inject for coronary x-rays) 93555 (imaging, cardiac cath)	1,220
SPECT	78465 (heart image (3d), multiple) 78478 (heart wall motion add-on) 78480 (heart function add-on) 93015 (cardiovascular stress test)	765
CCTA	0145T (CT heart w/wo dye funct:\$306) Physician fee (\$159) Buffer costs (\$269)*	735

20 *Goldstein 2008: Difference SPECT vs CCTA: \$30

One-way Sensitivity Analysis on CCTA Cost (30% CAD Prevalence)

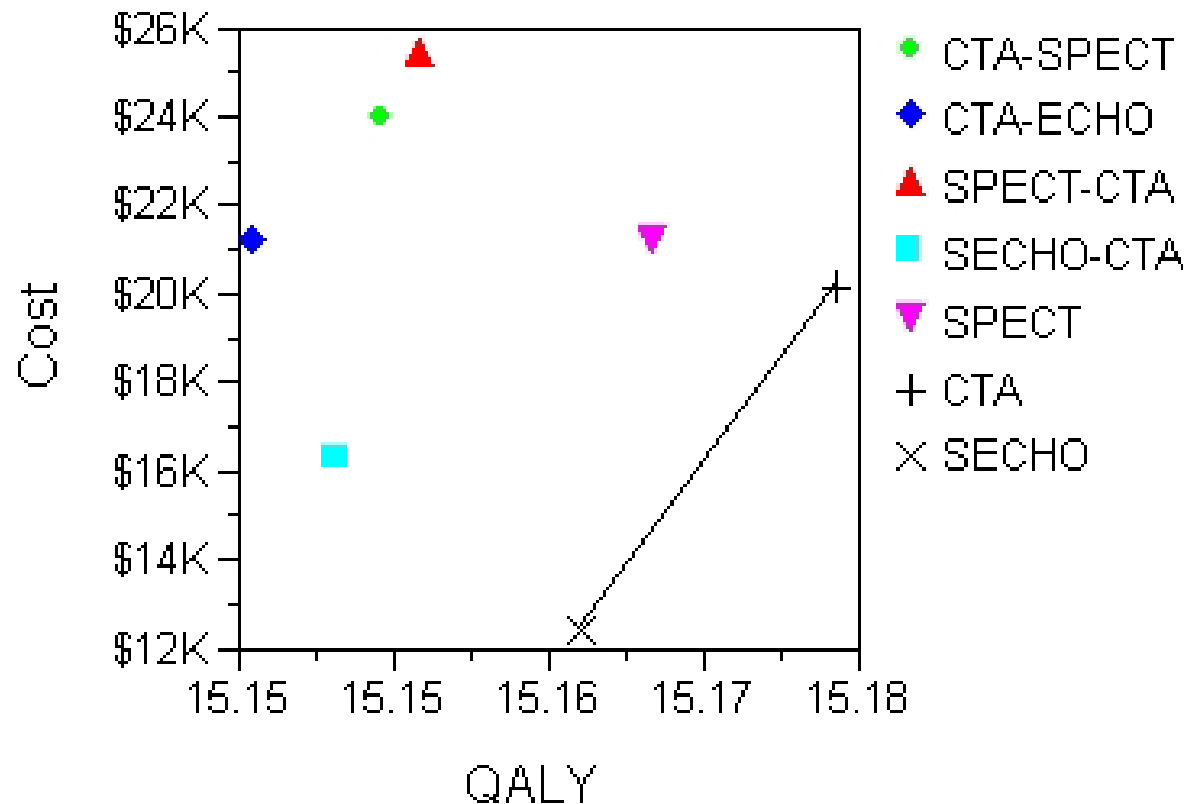
CCTA Cost: \$360						
Strategy	Effect	Incr. Effect	Costs	Incr. costs	C/E	Incr. C/E ¹
SECHO	15.167		12,580		829	
CCTA	15.183	0.016	13,799	1,219	909	74,277

CCTA Cost: \$950						
Strategy	Effect	Incr. Effect	Costs	Incr. costs	C/E	Incr. C/E ¹
SECHO	15.156		12,543		828	
SPECT	15.182	0.026	21,221	8,679	1,398	332,134
CCTA	15.186	0.004	23,979	2,757	1,579	782,503

Outpatient Model: Intermediate Outcome (30% CAD Prevalence)

Strategy	False-Negatives (per 1000)	Costs (per patient)	\$ per FN averted
SECHO	46	544	---
SECHO-CCTA	51	663	Dominated
CCTA	9	867	8,700
SPECT	24	967	Dominated
CCTA-SECHO	52	977	Dominated
CCTA-SPECT	31	1,110	Dominated
SPECT-CCTA	29	1,177	Dominated

Outpatient Model: Lifetime Results, 30% CAD Prevalence



QALY: Quality-adjusted life years

Outpatient Model: Results (per 1,000, 10% CAD prevalence)

	<u>CCTA</u>	<u>SPECT</u>	<u>SECHO</u>	<u>CCTA-> SPECT</u>	<u>SPECT-> CCTA</u>	<u>CCTA-> SECHO</u>	<u>SECHO-> CCTA</u>
True positive	98	92	84	92	91	84	83
False positive	112	183	92	30	34	14	26
True negative	788	717	808	870	866	886	875
False negative	2	8	16	8	9	16	17
Referred for ICA	57	113	147	43	37	53	35
ICA negative results	27	79	110	11	8	17	6
ICA related deaths	0.06	0.11	0.15	0.04	0.04	0.05	0.04
Exposed to radiation	1,000	1,000	147	1,000	1,000	1,000	299
Incidental findings requiring f/u	138	0	0	138	46	138	37
Total costs per patient [excluding FU]	804	903	479	949	1,052	863	537

Outpatient Model: Lifetime Results, 10% CAD Prevalence

Strategies Ordered by Increasing Effectiveness

Strategy	Effectiveness	Costs
SECHO	16.012	9,324
CCTA-ECHO	16.014	17,475
SECHO-CCTA	16.015	12,133
CCTA-SPECT	16.017	19,330
CCTA	16.018	17,110
SPECT-CCTA	16.024	21,393
SPECT	16.030	18,253

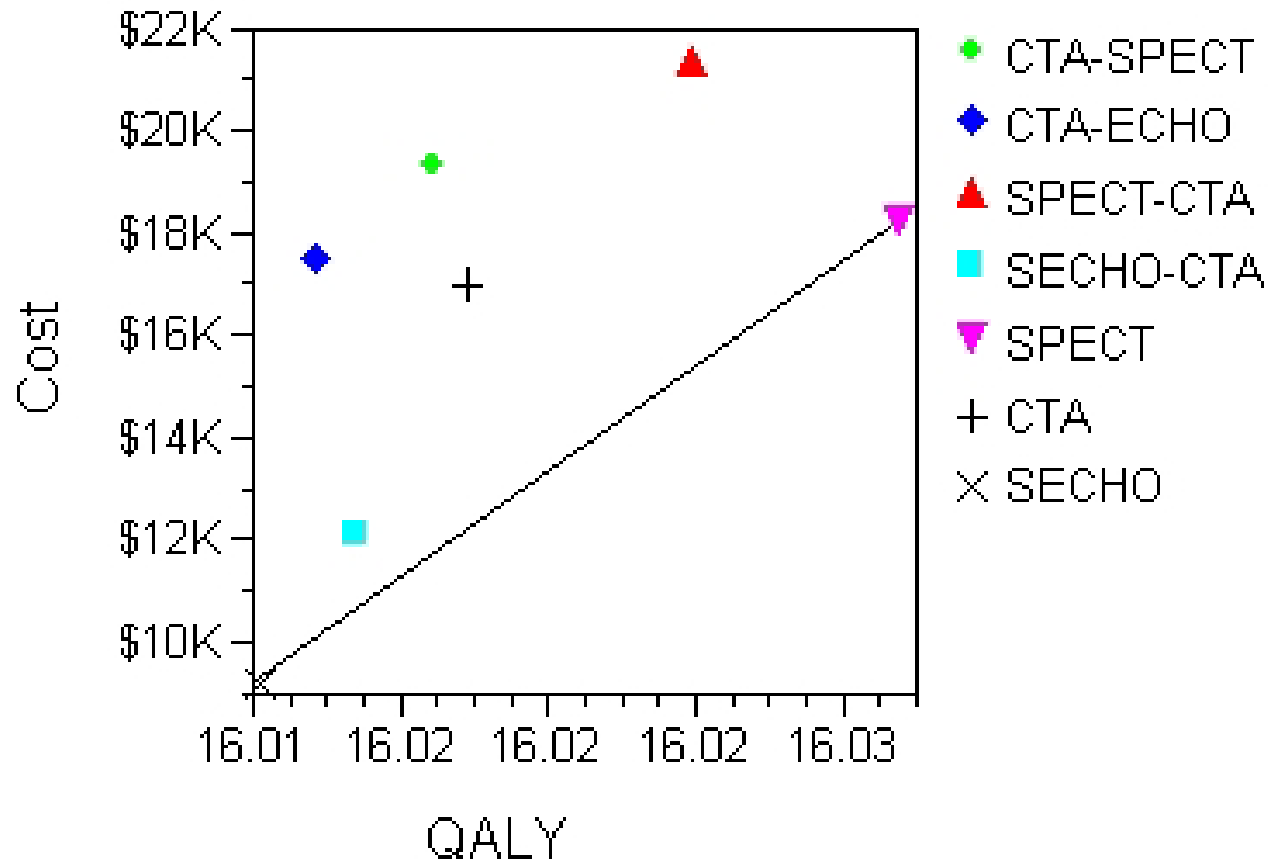
Incremental Cost-effectiveness Analysis

Strategy	Effect	Incr. Effect	Costs	Incr. costs	C/E	Incr. C/E ¹
SECHO	16.012		9,324		582	
SECHO-CCTA	16.015	0.003	12,133	2,808	758	1,101,189
CCTA	16.018	0.003	17,110	4,978	1,068	1,627,928
CCTA-ECHO	16.014	-0.004	17,475	365	1,091	(Dominated)
SPECT	16.030	0.012	18,253	1,143	1,139	97,542
CCTA-SPECT	16.017	-0.013	19,330	1,077	1,207	(Dominated)
SPECT-CCTA	16.024	-0.006	21,393	3,140	1,335	(Dominated)

Strategies without Dominated Options

SECHO	16.012		9,324		582	
SPECT	16.030	0.017	18,253	8,929	1,139	515,404

Outpatient Model: Lifetime Results, 10% CAD Prevalence



QALY: Quality-adjusted life years