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## Diagnostic Costs for Ischemic Heart Disease with Treadmill Stress Cardiac Magnetic Resonance and SPECT: Results of the Multicenter, Randomized EXACT-COST Trial

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### Keywords

myocardial perfusion imaging; SPECT; cardiac magnetic resonance; exercise stress

Vasodilator stress CMR offers superior accuracy over SPECT(1); however, pharmacological stress cannot reproduce exertional symptoms or signs. We have shown that MR-compatible treadmill stress with CMR offers excellent diagnostic performance vs. SPECT(2). Here, we compared exercise CMR and SPECT costs for ischemic heart disease (IHD) evaluation in a randomized trial ([NCT01875315](#)).

Adults referred for treadmill stress SPECT were enrolled across 4 centers: men age 30 years with chest pain/equivalents, diabetic women age >30 years and all women age 40 years with chest pain/equivalents, and individuals with known CAD. Excluded were those with contraindication to CMR or exercise stress(3). Subjects provided written informed consent to participate in this protocol approved across research committees.

Subjects randomized to SPECT underwent rest MPI followed by standard Bruce protocol stress and stress MPI. Those randomized to stress CMR had rest cines, then standard Bruce protocol stress. Acquisition of free-breathing cine and perfusion imaging commenced

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26.5±7.8 sec post-stress followed by recovery monitoring, resting perfusion and late gadolinium enhancement imaging(2). Referring physicians received standardized reports in both arms detailing exercise, symptoms, ECG, and imaging findings. Participants' baseline quality of life was recorded with the Duke Activity Status Index (DASI). Occurrence of IHD-related cardiac encounters and procedures were recorded for 12 months post-imaging stress test. Regional 2019 Medicare payments for each of the following CPT codes were recorded: stress SPECT, stress CMR, follow-up outpatient clinic visit, emergent visit, electrocardiogram, invasive coronary angiography, and stress echocardiogram.

Differences in continuous variables were analyzed using Student's t-test or the Mann-Whitney U test. Negative binomial regression was used to estimate the effect of modality on the rate of IHD-related outpatient clinic and observation unit encounters. A Linear mixed-effects modeling fit by restricted maximum likelihood was used to assess the impact of the modality on total cost adjusted for: participating center, age, sex, race, hypertension, diabetes, current smoking, test result, and baseline medications. We explored the impact of varying the cost difference between the 2 modalities, starting from 2019 national average Medicare payments for CMR and SPECT i.e. scenario\_1, where CMR cost = \$841.67 and SPECT cost = \$1,310.02. In scenario\_2, CMR cost was increased by \$200; in scenario\_3, SPECT cost was decreased by \$200; in scenario\_4, CMR cost was increased by \$400; and in scenario\_5, CMR cost was increased by \$200 and SPECT cost was decreased by \$400. A two-sided P-value <0.05 was considered statistically significant. Statistical analyses were performed using SPSS Statistics, version 22.0 (IBM, Armonk, USA) and R software, version 3.5.3 (R Foundation, Vienna, Austria).

Of 130 subjects randomized, 6 subjects in each arm did not complete stress imaging; the final study population comprised 59 SPECT and 59 CMR subjects. Participants had similar baseline characteristics and stress parameters such as duration of exercise ( $8.4 \pm 2.6$  min overall) and Duke treadmill score (8 [4–10] overall). SPECT subjects' total radiation dose averaged  $36.7 \pm 11.3$  mCi. Rates of abnormal stress results were similar: 34% in the SPECT arm, and 25% in the CMR arm ( $p=0.42$ ).

Over 12 months post-stress, IHD-related outpatient clinic and observation unit encounters totaled 95 in the SPECT arm and 57 in the CMR arm with no inpatient admissions, acute MIs, cardiovascular death, or heart failure. Stress SPECT had 1.667 (95% CI, 1.087 to 2.555) times more IHD-related encounters per patient-year of follow-up compared to stress CMR ( $p = 0.019$ ), remaining significant after covariate adjustment ( $p=0.03$ ). Median days off work during follow-up was 0.53, 0.29 for CMR subjects and 0.78 for SPECT subjects. Elective invasive coronary angiograms were done in 5 randomized to SPECT and 3 randomized to CMR; revascularization ensued in 1/5 SPECT vs. 2/3 CMR patients.

Twelve-month per-subject IHD costs, including the baseline imaging test, were higher for SPECT vs. CMR (\$1,594.69 [1,400.79 – 1,887.23] vs. \$976.10 [795.48 – 1,235.70],  $p<0.001$ ) remaining significantly higher with SPECT after covariates adjustment ( $p<0.001$ ). When further analyzed by stress imaging test result category, normal vs. abnormal (ischemia or infarct present), total costs remained lower with CMR ( $p<0.001$ ). CMR's cost savings remained significant by varying relative modality cost in all but scenario\_5. Across DASI

scores, cost of SPECT remained consistently higher than CMR (Figure). *Post hoc* power analysis indicated >99% power based on difference in the primary endpoint of 12-month IHD evaluation cost ( $\alpha=0.05$ ).

With stress CMR's effectiveness on par with invasive angiography with fractional flow reserve(4), our findings of cost savings likely translate to cost-effectiveness. In areas with similar relative cost of SPECT to CMR, our findings make a compelling case for exercise CMR as a first-line, cost-effective, and physiologically-informative stress modality to evaluate stable IHD without ionizing radiation. The perception of CMR as costly warrants reconsideration in light of these results endorsing stress CMR as a lower cost modality under current reimbursement models. Converting just 5 of the 55.8 annual stress SPECTs per 1000 Medicare part B beneficiaries(5) to stress CMR would translate to a potential annual cost savings in U.S. Medicare expenditures of > \$118M.

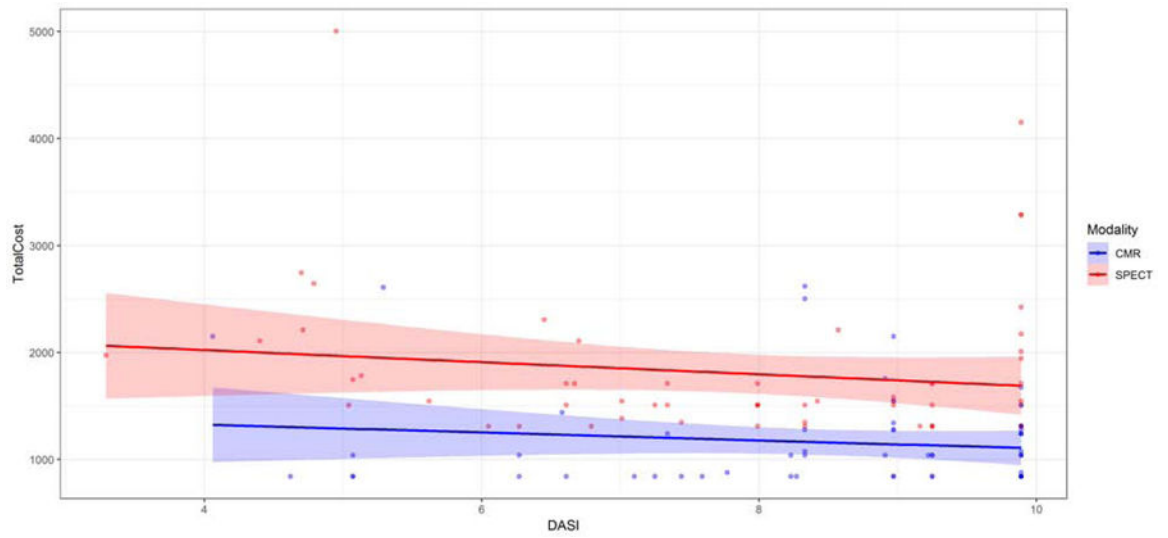
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## References

1. Greenwood JP, Maredia N, Younger JF et al. Cardiovascular magnetic resonance and single-photon emission computed tomography for diagnosis of coronary heart disease (CE-MARC): a prospective trial. *Lancet* 2012;379:453–60. [PubMed: 22196944]
2. Raman SV, Dickerson JA, Mazur W et al. Diagnostic performance of treadmill exercise cardiac magnetic resonance: the prospective, multicenter Exercise CMR's Accuracy for Cardiovascular Stress Testing (EXACT) trial. *J Am Heart Assoc* 2016;5.
3. Gibbons RJ, Balady GJ, Timothy Bricker J et al. ACC/AHA 2002 guideline update for exercise testing: summary article: A report of the American college of cardiology/American heart association task force on practice guidelines (committee to update the 1997 exercise testing guidelines) 1 2 3 4 5. *Journal of the American College of Cardiology* 2002;40:1531–1540. [PubMed: 12392846]
4. Nagel E, Greenwood JP, McCann GP et al. Magnetic Resonance Perfusion or Fractional Flow Reserve in Coronary Disease. *N Engl J Med* 2019;380:2418–2428. [PubMed: 31216398]
5. U.S. Centers for Medicare and Medicaid Services. Medicare provider utilization and payment data. <https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Medicare-Provider-Charge-Data/Physician-and-Other-Supplier.html> Accessed Oct 23, 2019.



**Figure.** Stress SPECT incurred higher 12-month cost for IHD testing vs. stress CMR across a range of Duke activity status indices ( $P<0.01$ ).