Prevalence and clinical characteristics of inappropriate myocardial perfusion imaging tests at a community hospital

Nadia Isabel Abelhad, Kendall J Kiser, Andres Hughes, Michael A Hust, Enrique Garcia Sayan, Siddharth K Prakash

BACKGROUND
Myocardial perfusion imaging (MPI) is a cornerstone for the diagnosis and management of patients with coronary artery disease (CAD). However, the persistence of inappropriate MPI tests as documented by meta-analyses undermines their clinical utility. Inappropriate MPI tests reduce diagnostic accuracy and increase false-positive results that can subject patients to unnecessary invasive procedures with additional risks, including radiation exposure, renal insufficiency and bleeding. Indirect effects at our hospital include prolongation of waiting time for procedures and referrals (currently 5 months for outpatient MPI) and consumption of limited healthcare resources ($350–$500 per test) in a predominately uninsured population. Inappropriate tests led to more than $500 million of additional costs in 2010 alone.

To address these challenges, cardiovascular societies promulgated appropriate use criteria (AUC) for MPI, and Congress directed the Centers for Medicare & Medicaid Services to consider AUC in reimbursement decisions. Risk calculators that emerged from these efforts are useful to identify appropriate patients who may benefit from MPI tests but remain underused. To investigate the utility of this approach, we evaluated the prevalence and characteristics of inappropriate MPI orders at one general community hospital.

RESULTS
Sixty-five subjects (49% female, 58% current or former smokers) met all inclusion criteria. The distribution of appropriate (78%), inappropriate (17%) and indeterminate (5%) MPIs was similar to historical data. However, the normalcy rate (30%) was significantly less than expected (90%) and was correlated with the prevalence of obesity. Elevated body mass index (34.0 in men and 37.1 in women) may result in decreased normalcy rates due to breast and/or abdominal attenuation. Seventy percent of MPI referrals, including all inappropriate referrals, originated from outpatient clinics. In contrast, none of the hospital inpatient (22%) or emergency department (8%) referrals were inappropriate. Inappropriate referrals were most frequently requested for patients with low pretest probabilities of CAD, as defined by a Diamond-Forrester Index (DFI) and atherosclerotic cardiovascular disease (ASCVD) calculators. Positive predictive values (PPVs) were calculated for >50% angiographic stenosis. Comparisons of categorical variables were evaluated using $\chi^2$ or Fisher exact tests. The severity of perfusion defects was compared using Spearman’s rank-order tests.

METHODS
We conducted a 3-month retrospective electronic medical record review of all patients (n=524) at a single hospital who were referred for MPI within 12 months of coronary angiography. Subjects who did not undergo prior MPI and subjects without complete clinical information were excluded (n=262). The appropriateness of MPI orders was adjudicated using the 2009 criteria for radionuclide imaging. Pretest probabilities of obstructive CAD were estimated using revised Diamond-Forrester Index (DFI) and atherosclerotic cardiovascular disease (ASCVD) calculators. Positive predictive values (PPVs) were calculated for >50% angiographic stenosis. Comparisons of categorical variables were evaluated using $\chi^2$ or Fisher exact tests. The severity of perfusion defects was compared using Spearman’s rank-order tests.
of targeted information sessions at the same hospital to promote provider awareness and to change test ordering patterns.  

Acknowledgements We sincerely thank LBJ Hospital, the Harris Health IT department for compiling our list of patients, the cardiology staff at LBJ for imaging and procedural reports, and the Harris Health Quality and Safety Committee for permitting our research.

Contributors SP and ES supervised the study. NA, KK, MH and AH abstracted clinical data. NA wrote the manuscript. SP, ES, KK and NA edited the manuscript.

Funding SP was supported by the Cheves and Isabella Smythe Distinguished Professorship in Internal Medicine.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The Committee for the Protection of Human Subjects at McGovern Medical School and the Harris Health System Office of Research and Sponsored Programs reviewed and approved the study protocol.

Provenance and peer review Not commissioned; externally peer reviewed.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, adequate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

REFERENCES

CONCLUSION
In a contemporary hospital-based cohort with prevalent CAD, we found that inappropriate MPI orders remain common and are related to predictable factors. Most inappropriate referrals originated from a small number of providers and involved low-probability patients who had normal left ventricular systolic function and did not present with typical anginal chest pain. The lower PPVs of inappropriate studies, in comparison with those of appropriate studies, are associated with diminished clinical utility for diagnosis and treatment. Inappropriate studies also increase the likelihood of potential harm from unnecessary interventions and exacerbate the misdirection of limited clinical resources. These observations highlight the potential financial and clinical impacts of educational interventions or interactive pop-up alerts in the electronic medical record to reduce inappropriate MPI referrals. We are currently assessing the effectiveness of targeted information sessions at the same hospital to promote provider awareness and to change test ordering patterns.

Table 1 Comparison of patients who underwent appropriate and inappropriate myocardial perfusion imagings stratified by pretest probabilities

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Inappropriate (n=10, 17%)</th>
<th>Appropriate (n=49, 78%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ejection fraction</td>
<td>Mean 58%</td>
<td>σ 4.5</td>
</tr>
<tr>
<td>Referral location</td>
<td>Outpatient 100%</td>
<td>Inpatient 100%</td>
</tr>
<tr>
<td>DFI*</td>
<td>&lt;10% 0.5</td>
<td>&gt;10%–90% 0.7</td>
</tr>
<tr>
<td>ASCVD score†</td>
<td>9.0% 8.0</td>
<td>17.4% 15.4</td>
</tr>
<tr>
<td>A1c level‡</td>
<td>5.9% 0.8</td>
<td>7.4% 2.0</td>
</tr>
</tbody>
</table>

*P=0.06. †P=0.08. ‡P=0.02.

ASCVD, atherosclerotic cardiovascular disease; A1c, haemoglobin A1c; DFI, Diamond-Forrester Index.

Table 2 The PPV of inappropriate MPI tests was lower than that of appropriate MPI tests

<table>
<thead>
<tr>
<th>Test result</th>
<th>Inappropriate (n=10)</th>
<th>Appropriate (n=52)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease status</td>
<td>+CAD</td>
<td>−CAD</td>
</tr>
<tr>
<td>Abnormal MPI</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Normal MPI</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>PPV</td>
<td>22%</td>
<td>49%</td>
</tr>
</tbody>
</table>

CAD, at least one >50% coronary lesion by coronary angiography; MPI, myocardial perfusion imaging; PPV, positive predictive value.