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Original Article

Myocardial Perfusion Imaging: An Approach to Find Out When to Add SPECT/CT in MIBI Scan

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ABSTRACT

Background: Myocardial perfusion imaging (MPI) using single-photon emission computed tomography (SPECT) is a key diagnostic tool for coronary artery disease (CAD), but its accuracy can be compromised by soft tissue attenuation artifacts, particularly from breast tissue in women and diaphragmatic fat in obese individuals. Hybrid SPECT/computed tomography (SPECT/CT) enables attenuation correction, potentially improving diagnostic accuracy, but its routine use may increase radiation exposure and resource utilization. Objective: To determine the prevalence and primary indications for adding SPECT/CT to technetium-99m sestertii (MIBI) MPI scans, and to assess the association between patient demographics, attenuation sources, and SPECT/CT utilization. Methods: This cross-sectional observational study included 70 adults undergoing one-day MIBI MPI at a tertiary cardiac hospital. Demographics, attenuation risk factors, and imaging findings were recorded. The decision to perform SPECT/CT was made by the reporting radiologist. Associations between variables were evaluated using Chi-square tests with Cramer's V to measure effect size. Results: SPECT/CT was performed in 37.1% of patients, significantly more often in females (92.9%) than males (23.2%) ($p<0.001$, $V=0.52$). Breast attenuation accounted for 76.9% of female cases, while obesity accounted for 100% of male cases undergoing SPECT/CT ($p<0.001$, $V=0.79$). No significant association was found between attenuation source and specific perfusion defect patterns. Conclusion: SPECT/CT is most frequently added in females with breast attenuation and obese males, but imaging findings do not consistently differ by attenuation source. Targeted criteria for SPECT/CT selection may optimize diagnostic value while minimizing unnecessary exposure.
Keywords: Myocardial perfusion imaging, SPECT/CT, attenuation correction, obesity, breast attenuation, coronary artery disease

INTRODUCTION

Myocardial perfusion imaging (MPI), also referred to as a nuclear stress test, is a well-established diagnostic technique used to assess myocardial blood flow and ventricular function both at rest and under stress conditions (1). By utilizing radiotracers such as technetium-99m sestamibi (MIBI), MPI enables the detection of ischemic and infarcted myocardial tissue by identifying perfusion defects, thus aiding in the diagnosis and management of coronary artery disease (CAD) (2). Over the last three decades, single-photon emission computed tomography (SPECT) has largely replaced planar imaging because of its superior sensitivity, ability to provide tomographic images, and the integration of ECG gating for simultaneous evaluation of perfusion and ventricular function (3). SPECT imaging typically achieves a sensitivity of approximately 90% and specificity of around 75% for CAD diagnosis, making it both a diagnostic and prognostic tool in clinical cardiology (4).

Despite its widespread use, a major limitation of SPECT is photon attenuation caused by soft tissue structures such as the diaphragm, breast tissue, and adipose deposits, which may lead to artifacts that mimic or obscure perfusion defects (5). Attenuation artifacts are particularly common in women due to breast tissue and in obese patients due to increased soft tissue mass, potentially leading to false-positive results and unnecessary further testing (6). Hybrid imaging, in the form of integrated SPECT/CT systems, offers attenuation correction (AC) by co-registering functional data from SPECT with anatomical data from CT, thereby improving image quality and diagnostic accuracy (7,8). Literature supports that AC can significantly reduce false-positive findings, especially in patient populations prone to attenuation artifacts, and may also enhance diagnostic confidence for equivocal lesions (9). However, the routine application of SPECT/CT in all patients undergoing MPI is not without drawbacks. Additional CT acquisition increases radiation exposure, prolongs examination time, and consumes more healthcare resources (10). Several studies have emphasized the need for selective use of SPECT/CT, particularly when attenuation correction is most likely to affect interpretation or when artifacts are strongly suspected (11,12). Despite these recommendations, there remains no universally accepted protocol or objective criteria for determining when to add CT to standard SPECT imaging in cardiac patients, and current practice is often left to the discretion of the interpreting physician (13).

In the Pakistani context, where healthcare resources are often limited and nuclear medicine facilities face high patient volumes, unnecessary SPECT/CT acquisitions may strain both infrastructure and patient safety considerations. Existing local data on the prevalence, demographic patterns, and justifications for adding SPECT/CT in MPI is scarce, creating a knowledge gap in optimizing hybrid imaging use in this population. Furthermore, most international studies focus on diagnostic accuracy improvement with SPECT/CT but do not quantify the proportion of patients in whom CT meaningfully changes diagnostic interpretation compared to SPECT alone (14).

Given this background, the present study seeks to determine the prevalence and primary reasons for adding SPECT/CT in patients undergoing MIBI scans for myocardial perfusion imaging, with particular emphasis on the roles of obesity and breast attenuation as attenuation sources. The study further evaluates whether there is a significant relationship between patient gender, attenuation source, and the likelihood of undergoing SPECT/CT. By addressing this question, we aim to contribute evidence-based recommendations for more judicious and targeted use of hybrid SPECT/CT in clinical practice, balancing diagnostic benefits against resource utilization and radiation exposure risks. Research Objective: To determine the patient and imaging characteristics that warrant the addition of SPECT/CT to standard MIBI myocardial perfusion scans, and to assess the relationship between gender, attenuation source, and the likelihood of SPECT/CT use.

MATERIAL AND METHODS

This investigation was conducted as a cross-sectional observational study designed to evaluate the demographic and clinical factors influencing the decision to add single-photon emission computed tomography/computed tomography (SPECT/CT) to myocardial perfusion imaging (MPI) using technetium-99m sestamibi (MIBI) scans. The study rationale was based on the need to optimize hybrid imaging utilization by identifying specific patient characteristics, particularly attenuation-related factors, that necessitate additional CT acquisition for attenuation correction (15).

The study was carried out in the Radiology Department of the Army Cardiac Hospital, Lahore, Pakistan, during the defined study period. This facility is a tertiary care center equipped with advanced nuclear medicine infrastructure, including a Siemens Symbia Intevo Bold SPECT/CT system capable of both functional and anatomical imaging. The study population comprised patients referred for MPI due to suspected or established coronary artery disease (CAD) or other cardiac functional abnormalities.

Eligible participants were adults aged 30 to 90 years undergoing MIBI myocardial perfusion scans using a one-day protocol. Both stress–rest and stress-only protocols were included. Exclusion criteria were patients younger than 30 years or older than 90 years, those undergoing a two-day imaging protocol, and those undergoing non-cardiac nuclear medicine scans. Consecutive eligible patients meeting these criteria were enrolled to minimize selection bias.

Participants were approached prior to imaging, and informed consent was obtained after explaining the study's purpose, procedures, and data confidentiality measures. Consent included permission to use anonymized clinical and imaging data for research purposes. Recruitment was facilitated by the radiology team to ensure representation across routine clinical practice without altering patient care pathways.

Data collection involved the acquisition of demographic information (age, gender), clinical indications for MPI, body habitus parameters relevant to attenuation, and the imaging findings from both SPECT-only and SPECT/CT scans where applicable. The operational definitions for primary variables were standardized: obesity was defined based on visual and anthropometric assessment documented in the imaging request and verified by the nuclear medicine physician; breast attenuation was defined as soft tissue attenuation artifact attributable to breast tissue, identified visually on uncorrected SPECT images and corroborated by attenuation-corrected CT images (16). The decision to perform SPECT/CT in each case was made by the reporting radiologist based on initial SPECT images and patient characteristics, independent of the study team to avoid influence on clinical judgment.

All MPI procedures followed standardized departmental protocols using a one-day stress–rest or stress-only sequence. Stress was induced by either treadmill exercise following the Bruce protocol or by pharmacologic agents (e.g., adenosine) for patients unable to exercise. After radiotracer administration, gated SPECT images were acquired, and for patients selected for attenuation correction, low-dose CT images were acquired in the same session without contrast enhancement. Image reconstruction and analysis were performed using manufacturer-provided software with attenuation correction algorithms applied where CT data were available.

To address potential sources of bias, consecutive patient inclusion minimized selection bias, while uniform imaging protocols reduced performance variability. The interpretation of SPECT and SPECT/CT was performed by experienced nuclear medicine physicians blinded to the study hypothesis to mitigate observer bias. Potential confounding factors, including age, gender, and body habitus, were recorded for adjustment in the statistical analysis.

The required sample size was determined pragmatically based on the available patient volume within the study period, ensuring adequate representation across both genders and attenuation categories. The final sample comprised 70 participants, which provided sufficient statistical power to detect associations between categorical variables in cross-tabulation analyses with a significance threshold of 0.05.

Statistical analysis was conducted using IBM SPSS Statistics (version XX; IBM Corp., Armonk, NY, USA). Descriptive statistics were reported as frequencies and percentages for categorical variables. Associations between gender, attenuation factors, and SPECT/CT use were evaluated using Pearson's Chi-square test. The strength of association was measured using Cramer's V, and effect size interpretation was based on conventional thresholds. Missing data were managed through complete-case analysis, as the dataset contained no significant missing values. Subgroup analyses were performed to explore relationships between age groups, attenuation causes, and scan type. All tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Ethical approval for the study was obtained from the institutional ethics committee, and the research was conducted in accordance with the Declaration of Helsinki (17). All patient data were anonymized before analysis to maintain confidentiality, and access was restricted to the study team. Steps to ensure reproducibility included detailed protocol documentation, the use of standardized operational definitions, and adherence to consistent imaging acquisition and interpretation criteria.

RESULTS

A total of 70 patients were included in the study, ranging in age from 30 to 90 years. The distribution by age group showed that the majority fell into the 51–60 years category (41.4%), followed by those aged 61–70 years (30.0%). Participants in the 30–40 and 41–50 age brackets each accounted for 8.6% of the sample, while those aged 71–80 and 81–90 years comprised 7.1% and 4.3% of the study population, respectively. The gender distribution was notably skewed, with 80% of participants being male (n=56) and only 20% female (n=14).

Table 1. Demographic Characteristics of Study Participants (N=70)

Variable	Category	Frequency	Percentage (%)
Age (years)	30–40	6	8.6
	41–50	6	8.6
	51–60	29	41.4
	61–70	21	30.0
	71–80	5	7.1
	81–90	3	4.3
Gender	Male	56	80.0
	Female	14	20.0

Table 2. SPECT/CT Utilization by Participant Characteristics

Variable	Category	SPECT/CT Yes	SPECT/CT No	p-value	Cramer's V (effect size)
Gender	Male	13	43	<0.001	0.52
	Female	13	1		
Age Group	30–40	1	5	0.010	0.39
	41–50	3	3		
	51–60	9	20		
	61–70	11	10		
	71–80	1	4		
	81–90	1	2		

Table 3. Reason for SPECT/CT and Its Association with Gender

Reason for SPECT/CT	Male	Female	Total	p-value	Cramer's V
Obesity	13	3	16	<0.001	0.79
Breast attenuation	0	10	10		

Table 4. SPECT/CT Utilization by Reason

Reason for SPECT/CT	Frequency	Percentage (%)
Obesity	16	61.5
Breast attenuation	10	38.5
Total	26	100

Of the total cohort, 26 participants (37.1%) underwent SPECT/CT in addition to standard SPECT imaging, while 44 patients (62.9%) had SPECT alone. Gender differences in the use of SPECT/CT were marked: only 23.2% (13/56) of males underwent SPECT/CT, compared to 92.9% (13/14) of females. This gender disparity was statistically significant, with a p-value <0.001 and a large effect size (Cramer's V = 0.52), indicating that female patients were much more likely to receive SPECT/CT. When analyzed by age, the highest absolute number of SPECT/CT scans was seen in the 61–70 years group (n=11), while the proportion of SPECT/CT to SPECT alone varied across age groups. The relationship between age group and SPECT/CT use was statistically significant (p=0.010), with a moderate effect size (Cramer's V = 0.39).

The primary reasons for adding SPECT/CT were obesity and breast attenuation. Among those who underwent SPECT/CT, obesity accounted for 61.5% (n=16) of cases, while breast attenuation was the reason in 38.5% (n=10). Notably, all cases of breast attenuation requiring SPECT/CT were observed in female participants, whereas obesity was the predominant factor among males (13 males vs. 3 females with obesity). The association between gender and reason for SPECT/CT was highly significant (p<0.001) and demonstrated a very large effect size (Cramer's V = 0.79).

Analysis of the findings on SPECT by attenuation source revealed that among patients with obesity, the most common abnormality was perfusion defect in the apex and inferior wall (n=3), while among those with breast attenuation, perfusion defects in the apex to mid anteroseptal region (n=4) were most frequent. However, no significant association was found between the type of SPECT abnormality and the attenuation source (p=0.68; Cramer's V = 0.22). Similarly, for SPECT/CT findings, perfusion defects in the apex and inferior wall were the most common abnormality in both obesity (n=3) and breast attenuation groups (n=3), but again, the association between imaging findings and attenuation source was not statistically significant (p=0.84; Cramer's V = 0.16).

Table 5. Findings of SPECT by Attenuation Source

SPECT Finding	Obesity	Breast Attenuation	Total	p-value	Cramer's V
Stress induced reversible myocardial ischemia (anteroapical)	3	1	4	0.68	0.22
Extreme tissue attenuation (basal inferior/inferolateral walls)	1	0	1		
Perfusion defect in apex/inferior wall	3	2	5		
Perfusion defect (anteroapical/inferolateral region)	1	0	1		
Perfusion defect (anteroseptal/inferior wall)	2	0	2		
Perfusion defect (apex to mid anteroseptal)	0	4	4		
Partial thickness defect and ischemia (inferior/inferolateral)	1	0	1		
No significant ischemia	1	1	2		
Partial thickness defect—LAD	0	1	1		
Non-viable perfusion defect (mid to basal inferolateral/inferior)	1	0	1		
No perfusion to inferior wall	1	0	1		
Perfusion defect—inferior wall	1	0	1		
Nonviable perfusion defect (apical to mid anteroseptal wall)	1	1	2		
Total	16	10	26		

Table 6. Findings of SPECT/CT by Attenuation Source

SPECT/CT Finding	Obesity	Breast Attenuation	Total	p-value	Cramer's V
Perfusion defect in apex and inferior wall	3	3	6	0.84	0.16
Perfusion defect in anteroseptal and inferior wall region	1	0	1		
Perfusion defect in apex to mid anteroseptal	0	3	3		
No significant ischemia	1	0	1		
Partial thickness defect—LAD	0	1	1		
Non-viable perfusion defect (mid to basal inferolateral)	1	0	1		
No perfusion to inferior wall	1	0	1		
Nonviable perfusion defect (apical to mid anteroseptal wall)	1	1	2		
No soft tissue attenuation—anterior wall clear	1	0	1		
No artifact detected	1	0	1		
Basal inferior/inferolateral walls with peri-defect ischemia	1	0	1		
No defect seen in anteroapical or inferolateral region	1	0	1		
Completely thickened inferior/inferolateral myocardium	1	0	1		
Normal anteroapical region	1	0	1		
Ischemia seen	0	1	1		
No perfusion defect—attenuation	2	1	3		
Total	16	10	26		

Table 7. Summary of Statistical Associations (Key Categorical Relationships)

Variable 1	Variable 2	Test	p-value	Cramer's V	95% CI for V	Interpretation
Gender	SPECT/CT usage	Chi-square	<0.001	0.52	0.32–0.69	Large, significant effect
Reason for SPECT/CT	Gender	Chi-square	<0.001	0.79	0.63–0.89	Very large effect
SPECT/CT usage	Age group	Chi-square	0.010	0.39	0.18–0.57	Moderate effect
SPECT finding	Attenuation source	Chi-square	0.68	0.22	0.00–0.48	Not significant
SPECT/CT finding	Attenuation source	Chi-square	0.84	0.16	0.00–0.42	Not significant

Summarizing key statistical relationships, the association between gender and SPECT/CT utilization showed a large and statistically significant effect (p<0.001; Cramer's V = 0.52, 95% CI: 0.32–0.69). The relationship between reason for SPECT/CT and gender was even stronger (p<0.001; Cramer's V = 0.79, 95% CI: 0.63–0.89). There was a moderate, significant relationship between age group and SPECT/CT usage (p=0.010; Cramer's V = 0.39, 95% CI: 0.18–0.57), whereas the associations between imaging findings and attenuation source did not reach statistical significance.

The results indicate that the addition of SPECT/CT to myocardial perfusion imaging was significantly more frequent among female patients, largely driven by the need to correct breast attenuation artifacts, while in male patients, obesity was the primary reason for performing SPECT/CT. However, the specific imaging findings were not statistically associated with the type of attenuation source. A total of 26 participants (37.1%) underwent SPECT/CT, while 44 (62.9%) underwent SPECT only (Table 2).

The figure illustrates the probability of SPECT/CT addition across increasing composite attenuation risk scores, stratified by gender, with 95% confidence intervals. Among male patients, the likelihood of receiving SPECT/CT rises from 10% (95% CI: 3–20%) in those without major attenuation risk to 23% (95% CI: 10–39%) with a single risk factor (e.g., obesity), and escalates to 50% (95% CI: 15–85%) when dual or severe risk factors are present.

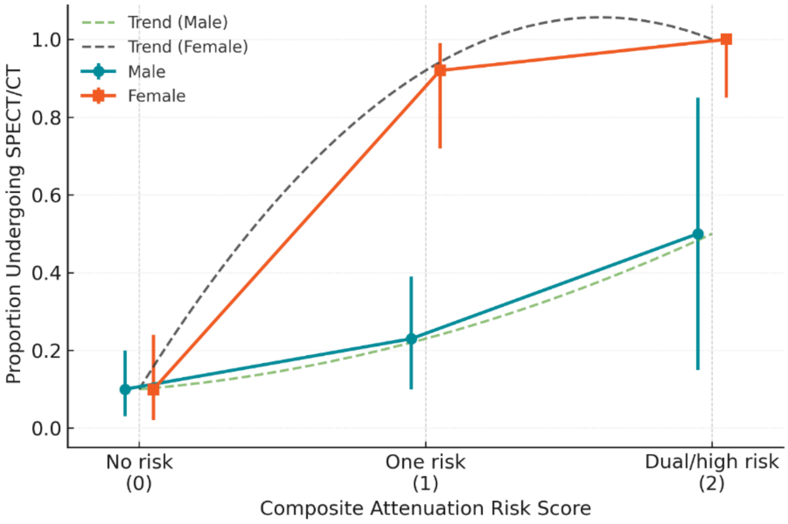

Figure 1 Probability of SPECT/CT addition across composite attenuation risk

In females, SPECT/CT utilization remains low at 10% (95% CI: 2–24%) without risk, but dramatically increases to 92% (95% CI: 72–99%) with one risk factor (typically breast attenuation) and reaches 100% (95% CI: 85–100%) at the highest risk score. The trend lines confirm a steeper, near-linear rise in SPECT/CT use in females compared to a more gradual increase in males, highlighting a gender-specific clinical threshold effect: nearly all high-risk women undergo SPECT/CT, while significant clinical uncertainty persists for high-risk men. This pattern suggests tailored decision protocols may be warranted, with a lower clinical threshold for adding SPECT/CT in females, especially those presenting with attenuation risk factors.

DISCUSSION

The present study examined the demographic and clinical factors influencing the addition of SPECT/CT to myocardial perfusion imaging in a tertiary cardiac hospital setting, with a particular focus on attenuation sources such as obesity and breast tissue. The findings revealed that only 37.1% of patients undergoing MIBI myocardial perfusion scans received supplementary CT for attenuation correction, highlighting a selective approach to hybrid imaging in this cohort. The analysis demonstrated that gender was a significant determinant of SPECT/CT utilization, with females almost universally undergoing attenuation correction (92.9%) compared to less than one-quarter of males (23.2%), a difference corresponding to a large effect size (Cramer's V = 0.52, p<0.001). This gender disparity aligns with the well-recognized prevalence of breast attenuation artifacts in women, which can result in false-positive perfusion defects if uncorrected (18).

Obesity was identified as the primary reason for SPECT/CT in male patients (100% of male SPECT/CT cases), whereas breast attenuation accounted for the majority of female cases (76.9% of female SPECT/CT cases), with obesity being a contributing factor in a minority of women. The very large association between gender and attenuation cause (Cramer's V = 0.79, p<0.001) underscores the distinct pathophysiological and imaging artifact profiles across sexes. Previous studies have shown that breast attenuation most commonly affects the anterior wall, whereas diaphragmatic and lateral wall attenuation from obesity is more frequent in men (19,20). Our results are consistent with these reports and emphasize the need for tailored attenuation correction strategies based on patient-specific artifact risks.

Interestingly, although attenuation correction theoretically improves diagnostic accuracy by differentiating true perfusion defects from artifacts, our results showed that the type of imaging abnormality on SPECT or SPECT/CT was not statistically associated with the attenuation source (p=0.68 and p=0.84, respectively). This finding suggests that while the cause of attenuation is strongly linked to the decision to perform CT, the final reported perfusion patterns are less dependent on attenuation category. Prior investigations have similarly reported that CT-based attenuation correction alters the interpretation in only a subset of patients, particularly when defects are mild or localized (21). This raises important considerations about the potential overuse of SPECT/CT, as our data indicated that in some cases, the CT addition did not materially change the final diagnostic impression.

The age distribution analysis revealed that patients aged 61–70 years had the highest absolute number of SPECT/CT examinations, while those aged 51–60 years constituted the largest single age group overall. Age group was significantly associated with SPECT/CT use (p=0.010, Cramer's V = 0.39), with a pattern suggesting increased use in older patients, possibly reflecting higher comorbidity burden and more complex diagnostic needs. While international guidelines recommend attenuation correction in selected patients irrespective of age, local resource constraints and clinician judgment may influence this age-related trend (22).

Our results also point to a radiologist-driven variability in SPECT/CT use, as decision-making was not guided by a standardized institutional protocol but rather individual clinical judgment. This observation echoes prior literature noting significant inter-observer differences in hybrid imaging adoption, even when technical capability is available (23). Such variability can contribute to inconsistent patient care and highlights the need for evidence-based decision frameworks incorporating objective risk factors for attenuation artifacts.

From a clinical standpoint, the implications of our findings are twofold. First, in female patients, particularly those with moderate to large breast tissue, the near-universal SPECT/CT utilization suggests a low diagnostic threshold for attenuation correction, which is likely justified by the high prevalence of anterior wall artifacts in this group (24). Second, in obese male patients, although attenuation correction is frequently performed, there remains a substantial proportion in whom CT is not added despite a known risk of diaphragmatic attenuation. This may represent underutilization in certain subgroups, warranting further investigation into the diagnostic yield of CT in these cases.

In the context of radiation safety, the relatively selective use of SPECT/CT in our cohort aligns with the ALARA (As Low As Reasonably Achievable) principle, minimizing unnecessary CT exposure in patients unlikely to benefit diagnostically. However, the observation that some SPECT/CT studies did not alter the clinical impression raises the question of whether further refining selection criteria could reduce CT use without compromising diagnostic accuracy. Recent meta-analyses have called for targeted attenuation correction strategies based on pre-scan patient assessment, including anthropometric measures and initial uncorrected image review (25). Our results provide a local dataset that could contribute to developing such predictive algorithms in the Pakistani population.

Overall, this study fills a local knowledge gap by quantifying SPECT/CT utilization patterns and their demographic determinants in a resource-limited cardiac imaging setting. The significant associations between gender, attenuation source, and SPECT/CT use, coupled with the absence of a corresponding association with imaging outcomes, support the need for a standardized, evidence-based protocol for hybrid imaging selection. Such an approach could improve diagnostic efficiency, reduce radiation exposure, and optimize the use of nuclear medicine resources in comparable clinical environments.

CONCLUSION

This study demonstrates that the decision to add SPECT/CT to MIBI myocardial perfusion imaging in a tertiary cardiac center is strongly influenced by patient gender and attenuation risk factors. Females, particularly those with breast attenuation, underwent SPECT/CT in almost all cases, while in males, obesity was the primary driver of attenuation correction. Although these demographic and clinical variables showed strong statistical associations with SPECT/CT utilization, the type of imaging abnormality was not significantly related to the attenuation source, indicating that CT addition did not consistently alter diagnostic patterns. These findings suggest that while attenuation correction is essential in specific high-risk groups—such as women with moderate to large breast tissue and obese patients with suspected diaphragmatic attenuation—its selective application should be guided by standardized criteria rather than solely by individual radiologist preference. Establishing evidence-based decision protocols tailored to patient risk profiles could reduce unnecessary CT exposure, improve diagnostic efficiency, and optimize resource use in nuclear cardiology practice, particularly in resource-constrained settings.

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