

A decision tree model for evaluating the cost effectiveness of Single-Photon Emission-Computed Tomography compared with stress echocardiography for diagnosis of coronary artery disease

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Abstract

Background Early diagnosis of coronary artery disease is very vital for success in treatment of this disease. However, the appropriate diagnostic modality for diagnosis of coronary artery disease is uncertain. Therefore, we conducted this study to compare the cost-effectiveness of Single-Photon Emission-Computed Tomography (SPECT) versus stress echocardiography for diagnosis of coronary artery disease in Iran.

Methods A decision tree model was developed to compare the cost-effectiveness of SPECT versus stress echocardiography. This study was conducted in Tehran, capital of Iran, between April 1, 2017, and September 1, 2018. The cost analysis was conducted from a societal perspective and medical direct costs, nonmedical direct costs and indirect costs were estimated.. Effectiveness was defined as the accurate detection of coronary artery disease and invasive coronary angiography was used as a gold standard. The incremental cost-effectiveness ratio was defined as an additional cost per correct diagnosis.

Results SPECT was associated with higher costs and lower effectiveness compared with stress echocardiography. Therefore stress echocardiography is dominant alternative compared to SPECT. The results also indicated that total cost per patient were \$970.49 and \$781.8 for SPECT and stress echocardiography, respectively. Also, the percent of true positive and true negative responses were %88 and %79 for SPECT and %90 and %92 for stress echocardiography.

Conclusions The results of this study indicate that stress echocardiography is the cost-effective modality in the diagnosis of coronary artery disease compared with SPECT. According to the results, it is suggested cardiologists use stress echocardiography instead of SPECT for the diagnosis of coronary artery disease. The result of the current study has significant concepts for decision-making in designing clinical guidelines for the diagnosis of coronary artery disease.

Background

Cardiovascular disease (CVD) has become one of the most common Non-Communicable Diseases (NCDs) throughout the world and it is responsible for about 40% of all NCD deaths [1–3]. One of the most common CVDs is Coronary artery disease (CAD) that leads to a considerable increase in mortality and morbidity [4]. CAD is responsible for more than 30% of all deaths and about 40% of cardiovascular deaths [4, 5]. Based on previous studies, CAD is accounted for about 500 thousand deaths in the USA and almost 2 million deaths in Europe annually [6]. Also, it is reported that about 50% of all deaths in Iran are due to CAD [7]. An important point is that about one half of all CAD deaths occurred suddenly and unexpectedly. On the other hand, almost 50% of CAD deaths in developing countries occurred in people aged below 70 years [8, 9]. However, CAD is one of the most preventable diseases and it is reported that early diagnosis can lead to about 80% decrease in deaths relating to CAD [10, 11].

Therefore, early diagnosis of CAD is very essential for success in treatment of this disease. Several modalities are used to diagnose CAD including invasive and non-invasive modalities. Invasive strategies such as angiography for CAD diagnosis is expensive and with adverse side effects. Therefore, it is better than cheaper, non-invasive, easily available and more effective modalities are used for diagnosis of CAD [12]. Non-invasive modalities such as stress echocardiography and Single-Photon Emission-Computed Tomography (SPECT) diagnose the CADs without break in the skin [13]. Among non-invasive methods, the use of stress echocardiography is widespread in people who are unable to exercise, such as patients with peripheral vascular disease, myocardial infarction, and orthopedic disorders [14]. Stress echocardiography is a very suitable, adaptable and cheap tool with a wide use for non-invasive imaging of the heart [15]. Stress echocardiography works similar to CT-scan, but the advantage of stress echocardiography is the reduction of radiation exposure to the patient compared to CT-scan [16, 15]. Also, previous studies showed that SPECT has a high diagnostic value in the diagnosis of CAD and has been proposed as an important diagnostic modality for patients [17]. However, there are significant differences between the two diagnostic methods in terms of cost and effectiveness. In various studies, the cost of SPECT is estimated at between \$ 5,417 and \$ 20,550 per correct diagnosis of heart disease. Also, the cost per QALY for the SPECT method is estimated at \$ 38,000 to \$ 40,316, which is much higher than the stress echocardiography method [18, 19]. Although SPECT is much more expensive than stress echocardiography, it has shown better negative predictive value than stress echocardiography [20, 21].

Due to significant differences between SPECT and stress echocardiography, economic evaluation studies tried to examine the cost-effectiveness of these diagnostic methods. However, there is no evidence about the superiority of one of these methods [22–24]. Therefore, we conducted this study to evaluate the cost-effectiveness of SPECT compared to stress echocardiography in Iran.

Methods

This cross-sectional, cost-effectiveness study was conducted in three general hospital in Tehran, capital of Iran, between April 1, 2017 and September 1, 2018. We used a decision tree model to find the cost effective modality for diagnosis of CAD. All persons suspected to CAD that used SPECT or stress echocardiography were studied. The response of each diagnostic modality was positive or negative. The prognostic value of this modalities were assessed by invasive coronary angiography as a gold standard [25]. Finally, terminal nodes for each modality in decision tree model were true positive, true negative, false positive, false negative. Decision tree algorithm is shown in Fig. 1.

In this study, the societal perspective was selected for calculating the costs. This perspective is including medical direct costs (diagnostic modalities, visits, surgical costs, hoteling, drugs, ECG, laboratory tests, consumables) and nonmedical direct costs (traveling, accommodation, phone) and indirect costs (time costs imposed on patient, time costs imposed on patient's accompany). Medical direct costs were extracted from patient's medical records and non-medical direct and indirect costs were collected by interviewing of the patient. It is necessary to mention that the indirect costs were calculated using human capital approach [26]. In our one-year study period, the discount rate was not used. All costs were

converted to US dollars using the average exchange rate Central Bank of Iran for the time period of this study. According to this, one dollar is equal to 36692 Iranian Rials. We used the percent of correct diagnosis as the outcomes of each diagnostic modalities in decision tree model. In this step, invasive coronary angiography used as a gold standard for evaluation of SPECT and stress echocardiography in CAD diagnosis [25]. The incremental cost-effectiveness ratio (ICER) was defined as the difference cost to difference effectiveness (correct diagnosis).

We used SPSS 16 and TreeAge 2011 software and a decision tree model for data analysis. TreeAge provides a popular approach for model simplification to compare the cost effectiveness of alternative strategies. Furthermore, we performed a sensitivity analysis for improving the accuracy of the study.

Results

Table1 shows the demographic characteristics of patients included in this economic evaluation study. A total of 510 patients were included in this study. According to the results of this study, the mean age of patients in SPECT and Stress echocardiography was 60 and 56 years respectively. More than %50 of patients in both group were woman, married and with university education.

Table1 demographic characteristics of patients

Variation		Diagnostic modalities	
		SPECT	Stress echocardiography
Age		60.84±56.11	56.89±53.16
Sex	Men	%44	%37
	Women	%56	%63
Marital status	Married	%61	%55
	Single	%39	%45
Education	University education	%40	%43
	Non-university education	%60	%57

The mean cost of CAD diagnosis in two groups of diagnostic modalities is compared in table 2. This table shows that medical direct costs and non-medical direct costs in both groups were the highest and lowest cost respectively. As seen in table 2, the surgical costs were the highest type of medical direct costs in both group (233.75 and 201.8 US\$ in SPECT and Stress Echocardiography, respectively). The highest non-medical direct cost was related to traveling (\$49.7 in SPECT group vs \$43 in Stress echocardiography group). The time costs imposed on patients were the highest type of indirect costs in both arms (\$ 88.7and \$76.3 in SPECT and Stress echocardiography, respectively).

Table 2 the cost items for CAD diagnosis

Costs		Diagnostic modalities (Average costs)	
		SPECT	Stress echocardiography
Medical direct costs	diagnostic modalities	233.34	131.8
	Visits	9.1	9.3
	surgical costs	233.75	201.8
	Consumables	126.4	110
	Drugs	9	11.6
	ECG	6.4	6.7
	laboratory tests	8.2	8.5
	Hoteling	114.5	103.3
	Total	740.69	583
Non-medical direct costs	Traveling	49.7	43
	Accommodation	19.8	18.6
	Phone	30.1	22.9
	Total	99.6	84.5
Indirect costs	For patients	88.7	76.3
	For patient's accompany	41.5	38
	Total	130.2	114.3

Cost-Effectiveness results:

The results of cost-effectiveness analysis of SPECT compared with stress echocardiography have been indicated in Table 3. The results showed that Stress echocardiography have an expected cost equal to \$316.3 s and an expected effectiveness equal to 0.84. Our results also showed that in the SPECT arm, the expected cost was \$656.6 dollars and the expected effectiveness was 0.69. As a result, stress echocardiography is dominant compared to SPECT (less costly and more effective).

Table 3 The result of cost -effectiveness analysis of SPECT vs Stress echocardiography

Diagnostic modalities	Cost (USD)	Effectiveness	ΔC	ΔE	SPECT vs Stress echocardiography
Stress Echo	316.3	0.84			Dominated
SPECT	656.6	0.69	340.3	-0.16	

ΔC = cost difference

ΔE = effectiveness difference

Cost effectiveness results of two diagnostic modalities were compared in figure 2. The dominant strategy, Stress echocardiography, is shown with a square in figure 2 (less costly and more effective). Also, SPECT as a dominated strategy is shown with the triangle (more costly and less effective).

Sensitivity analysis

To cope with uncertainty, we performed a sensitivity analysis that shown in Tornado diagram (Figure 3). In one-way sensitivity analysis, we increased all parameters to 20%. Then, we examined the changes in the ICER using one-way sensitivity analysis. Tornado diagram showed that ICER has the highest sensitivity to changing in the true positive cases in the stress echocardiography arm.

Discussion

The purpose of any economic evaluation study, especially in the field of medical decision-making, is to raise the awareness of policy makers about the costs and effectiveness of alternative therapies, technologies and interventions for a disease. Therefore, we conducted this study to evaluate the cost-effectiveness of SPECT compared to stress echocardiography in Iran.

According to the results of our study, the mean of medical direct costs was the highest cost in both groups. This is consistent with previous works [27, 28]. The results of medical direct costs for diagnostic modalities (SPECT and stress echocardiography) showed that SPECT was more expensive than stress echocardiography (\$233.3 vs \$131.8). Also, total medical direct costs per patient (the costs of diagnostic modalities plus angiography) were \$740.6 in the branch of SPECT and \$583 in the branch of stress echocardiography. Both of the non-medical direct costs and indirect costs in the branch of SPECT was more than stress echocardiography. Lee et al in a study entitled "Cost-effectiveness of coronary CT angiography in patients with chest pain: Comparison with myocardial single photon emission tomography" showed that the medical direct cost for SPECT is \$332. In this study, the cost of angiography was estimated about \$601 [29]. In another study, the cost of SPECT cost was \$300 whereas the cost of stress echocardiography was \$120, and for coronary angiography was \$1200 [30]. Hlatky et al

in an economic outcomes study calculated the costs of Coronary Anatomy Imaging modalities. In this study, the costs of SPECT, PET and computed tomography angiography (CTA) were calculated for 2-years. The most expensive and cheapest diagnostic modalities were PET and SPECT respectively. The mean costs of PET, CTA and SPECT for 2-years were \$6,647, \$4,909 and \$3,965 [31]. Van der Wall et al. conducted a cost analysis study on diagnostic modalities (including CTA, PET and SPECT) for diagnosis of suspected CAD. This study showed that SPECT is much more cheaper than CTA and PET over 2 years follow-up of suspected CAD patients [32]. However, it is reported that SPECT is significantly more expensive compared with stress echocardiography for CAD diagnosis [33].

In this cost-effectiveness study, we estimated the percent of true positive and true negative responses for each diagnostic modality. The percent of true positive and true negative responses were %88 and %79 for SPECT and %90 and %92 for stress echocardiography. The results of previous studies about comparison of correct responses of this two diagnostic modalities were Contradictory. However, it is claimed that stress echocardiography is a useful diagnostic technology for CAD diagnosis. In an evidence-based study, the overall pooled sensitivity and specificity for stress echocardiography was 0.80 and 0.84 using invasive angiography as a gold standard [34]. A systematic review analysis showed that sensitivity for stress echocardiography can be variable between %53 and %91 and specificity between %44 and %94 [35]. sensitivity and specificity for SPECT reported %70 and %76 respectively [36]. However, another study showed that sensitivity and specificity of SPECT in CAD diagnosis was %83 and %89 [37].

The results of this study revealed that stress echocardiography has lower costs and more effectiveness (dominant) compared with SPECT and stress echocardiography is the most cost-effective strategy against SPECT. Many studies evaluated the cost effectiveness of non-invasive Imaging modalities for the diagnosis of CAD. Javan-Noughabi et al in a systematic review on economic evaluation of SPECT for diagnosis of CAD indicated that SPECT is an attractive strategy compared with PET and CTA. But, SPECT in comparison with stress echocardiography, DECT and CMR was a dominated modality [38]. In a systematic review on the cost effectiveness of stress echocardiography against other non-invasive imaging modalities for the diagnosis of CAD, the results showed that stress echocardiography is cost effective compared with SPECT in the majority of included study [34]. Bedetti et al in a study entitled "Economic analysis including long-term risks and costs of alternative diagnostic strategies to evaluate patients with chest pain" showed that the cost of SPECT is more than 2 times expensive than stress echocardiography. In this study, stress echocardiography was the dominant modality versus SPECT (ICER defined as cost per patient correctly identified) [39]. One obvious limitation in this economic evaluation study was that decision tree model used for short treatment period (1-year), whereas CAD is a chronic disease requiring long-term treatment. This may limit the generalizability of results.

Conclusions

The results indicate that stress echocardiography is the most cost-effective strategy against SPECT in diagnosis of coronary artery disease. According to the results, it is suggested cardiologists use stress echocardiography instead of SPECT for the diagnosis of coronary artery disease. The result of the current

study has significant concepts for decision-making in designing clinical guidelines for the diagnosis of coronary artery disease.

Declarations

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Authors' contributions:

Designing the study, data collection, analysis, drafting the first version of the article and finalization of the article conducted by JJN. AR, MH and VA cooperated in study design and data collection. Other authors provided critical comments on this manuscript. All authors read and approved the final manuscript.

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Competing interests:

The authors declare that they have no Competing interests.

Availability of data and materials:

All data are available on reasonable request.

Ethics approval and consent to participate:

Ethical approval for this study was obtained from Ethics Committee of the Iran University of Medical Sciences. Informed and verbal consent was obtained from participants before data collection.

Consent for publication:

Consent for publication is not applicable as this study did not include names, images, or videos relating to individual participants.

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Figures

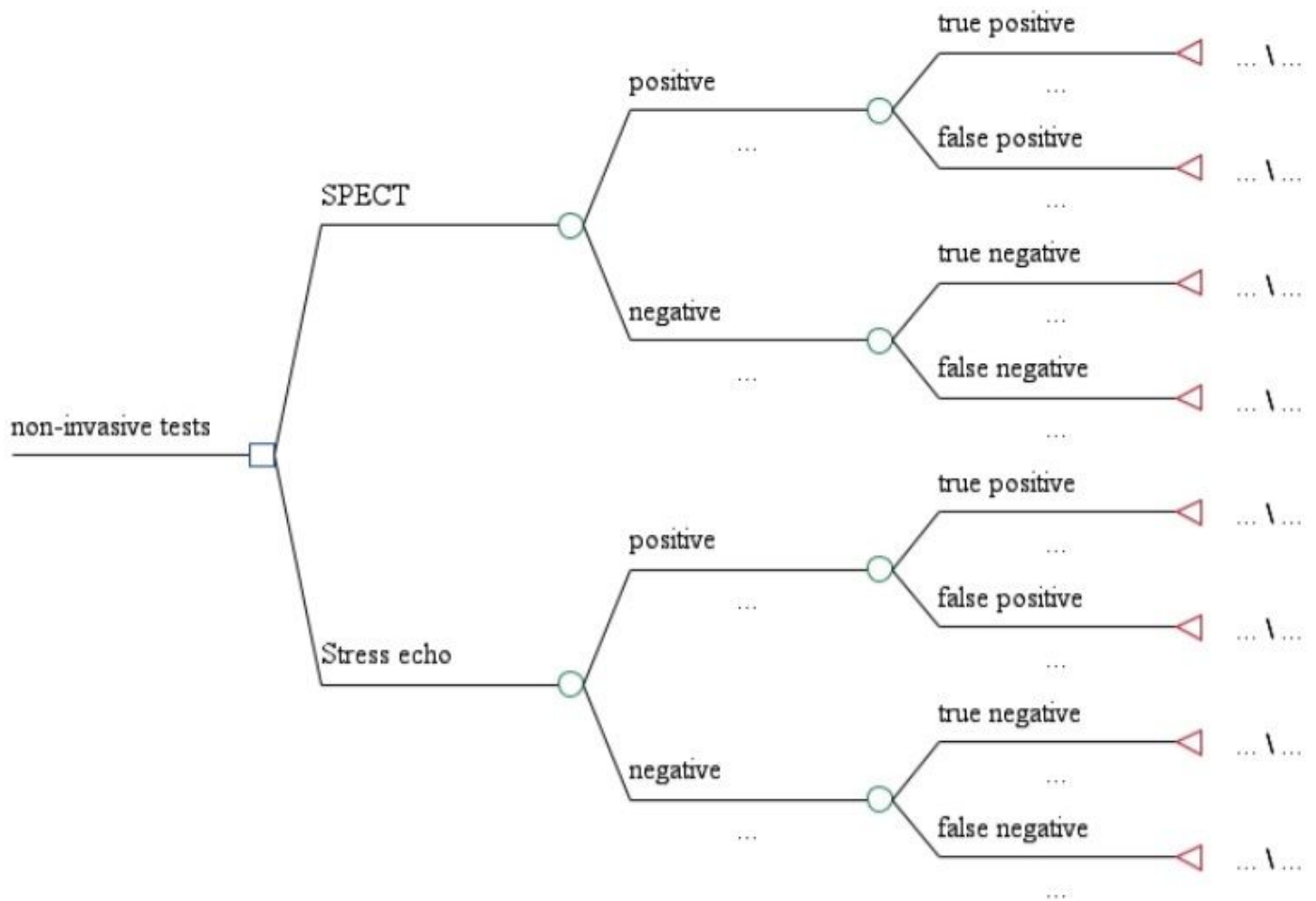


Figure 1

Decision tree algorithm for the cost-effectiveness of SPECT versus Stress echocardiography in diagnosis of CAD

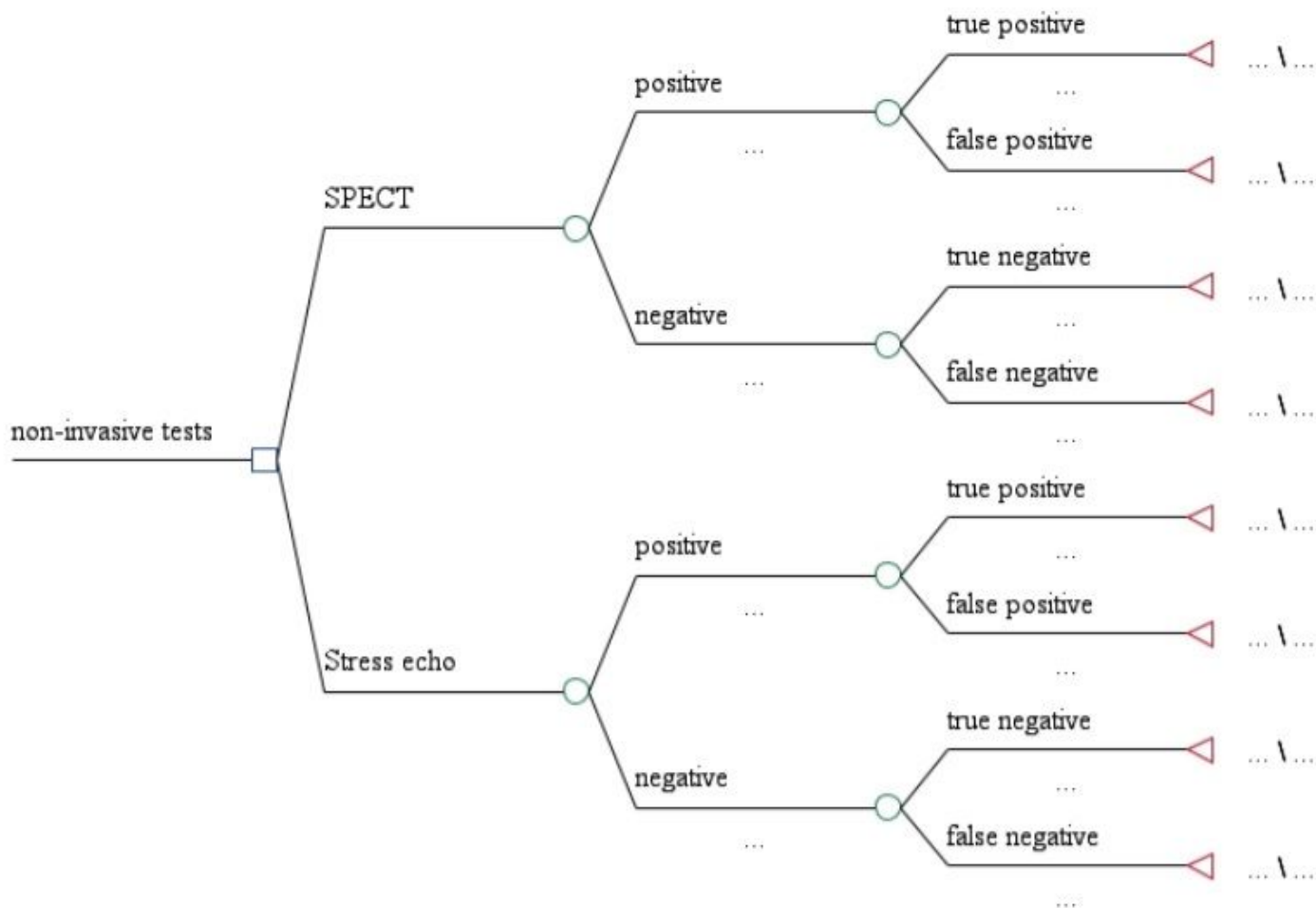


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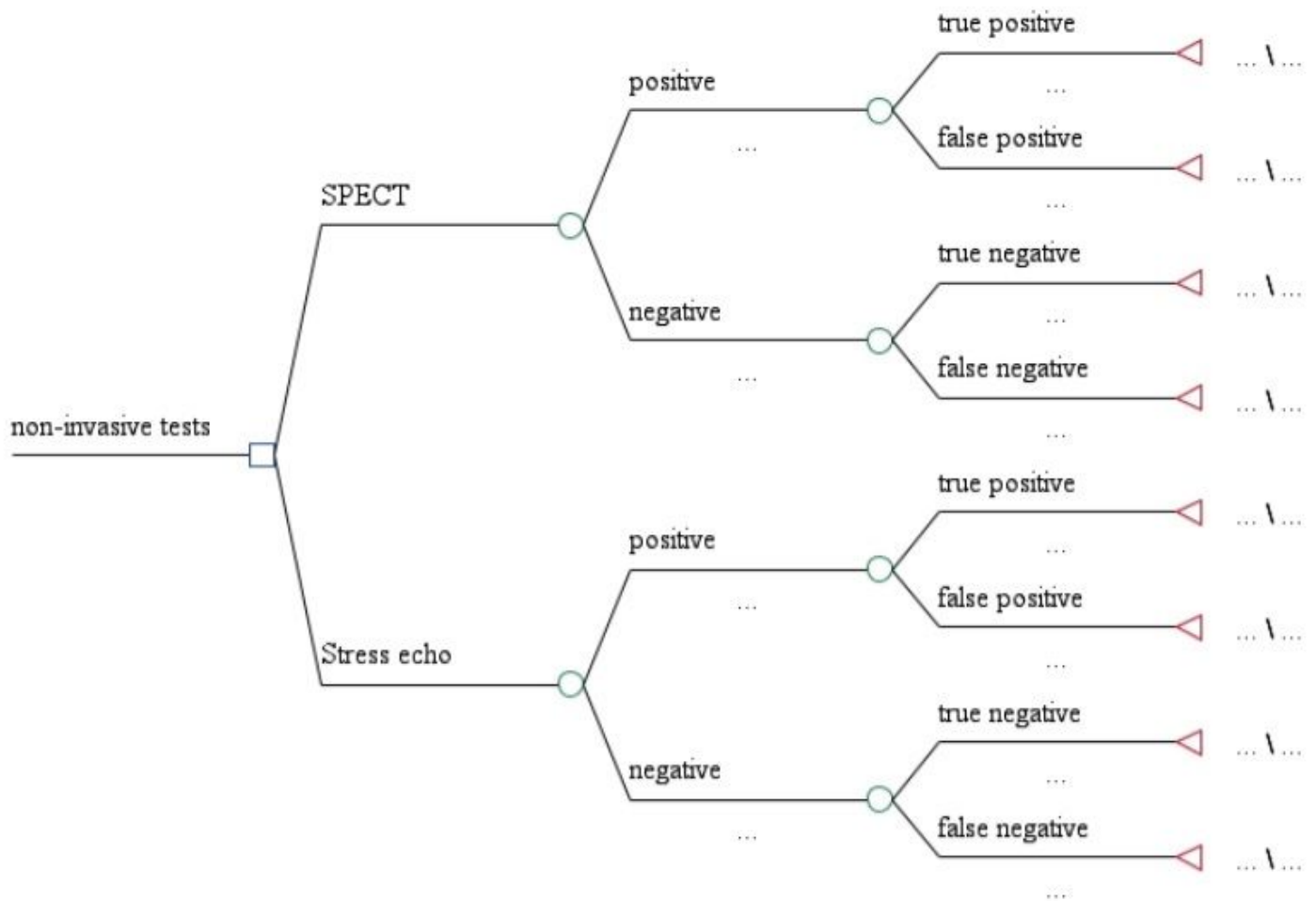


Figure 1

Decision tree algorithm for the cost-effectiveness of SPECT versus Stress echocardiography in diagnosis of CAD

Cost-Effectiveness Analysis

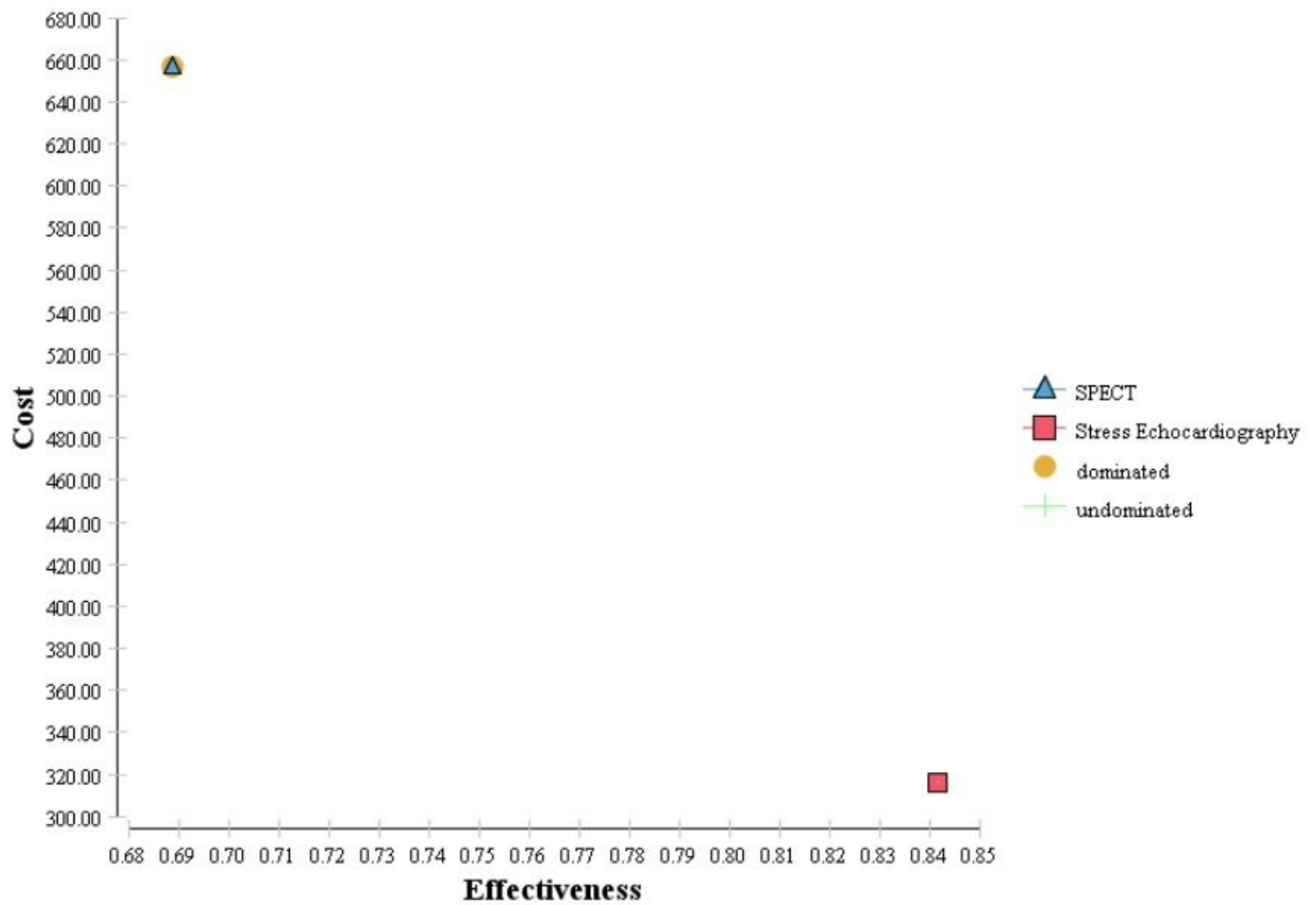


Figure 2

Cost-effectiveness analysis of SPECT versus Stress echocardiography in diagnosis of CAD

Cost-Effectiveness Analysis

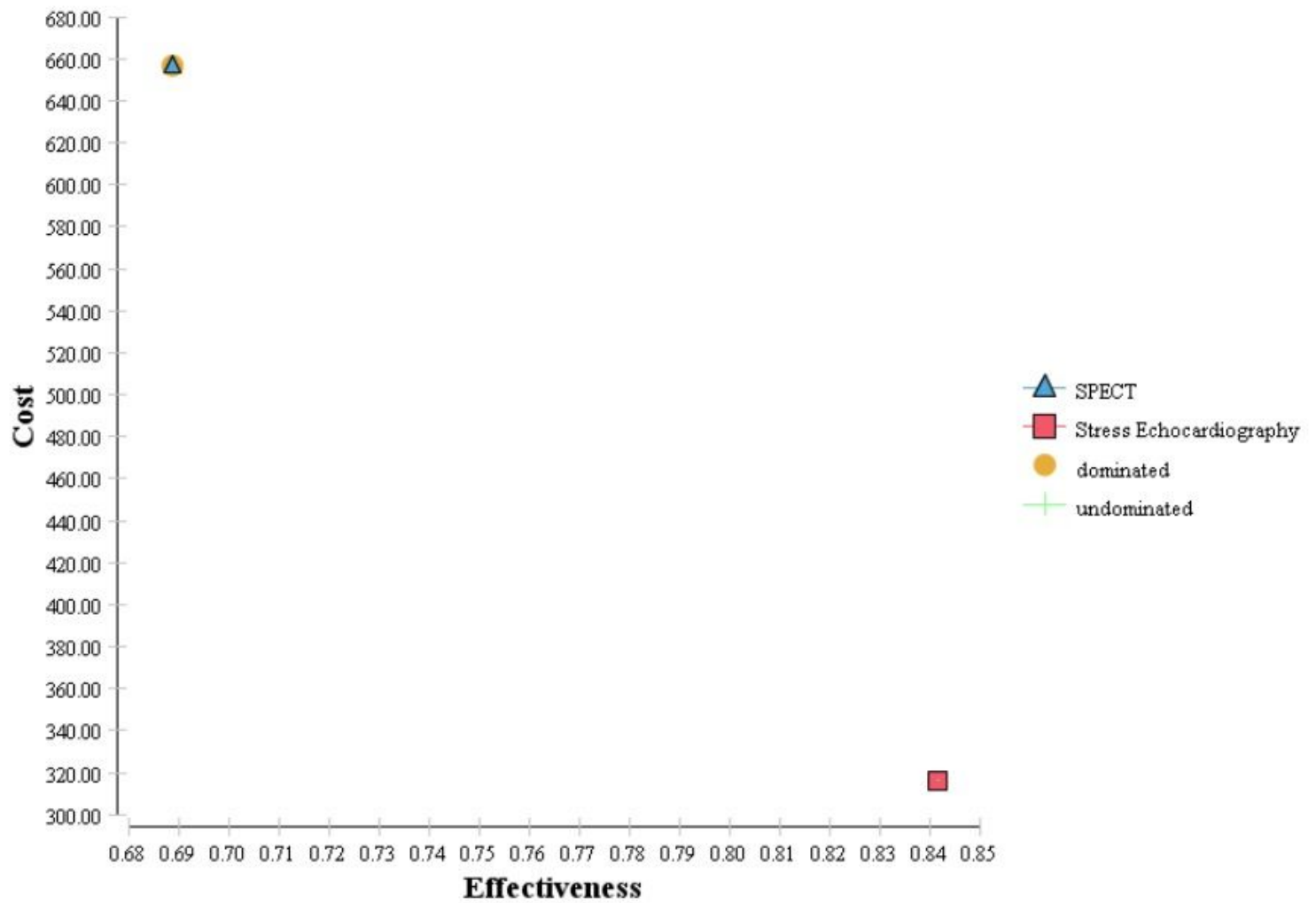


Figure 2

Cost-effectiveness analysis of SPECT versus Stress echocardiography in diagnosis of CAD

Cost-Effectiveness Analysis

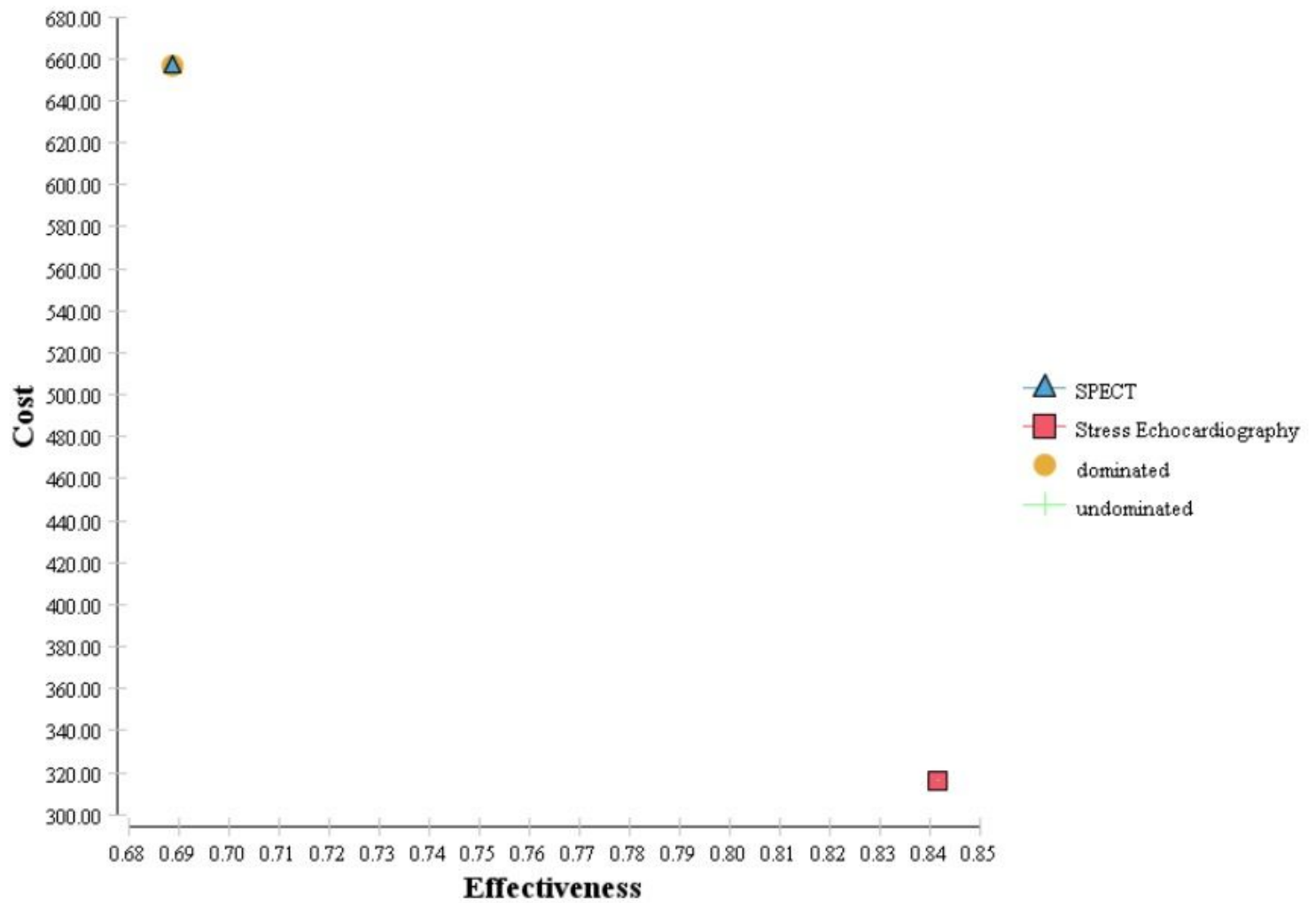


Figure 2

Cost-effectiveness analysis of SPECT versus Stress echocardiography in diagnosis of CAD

Tornado Analysis (ICER)

True negative in branch of stress echo

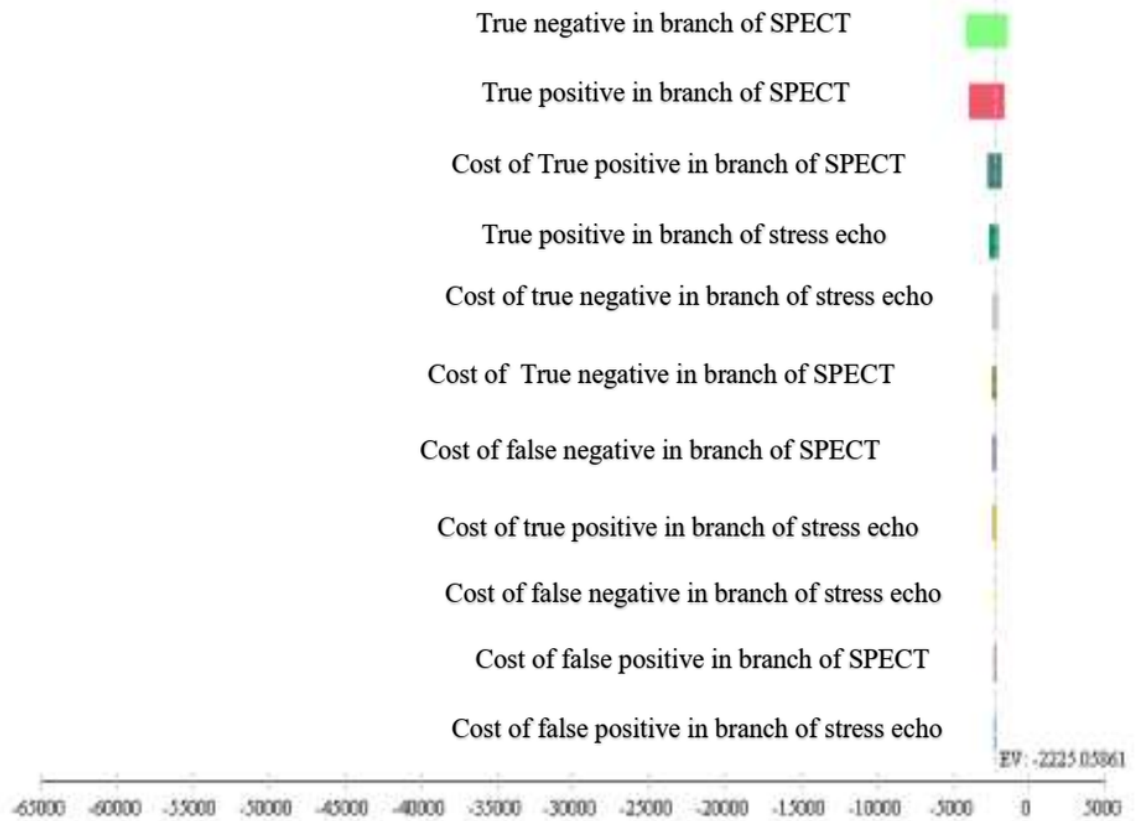


Figure 3

Tornado diagram for one-way sensitivity analysis

Tornado Analysis (ICER)

True negative in branch of stress echo

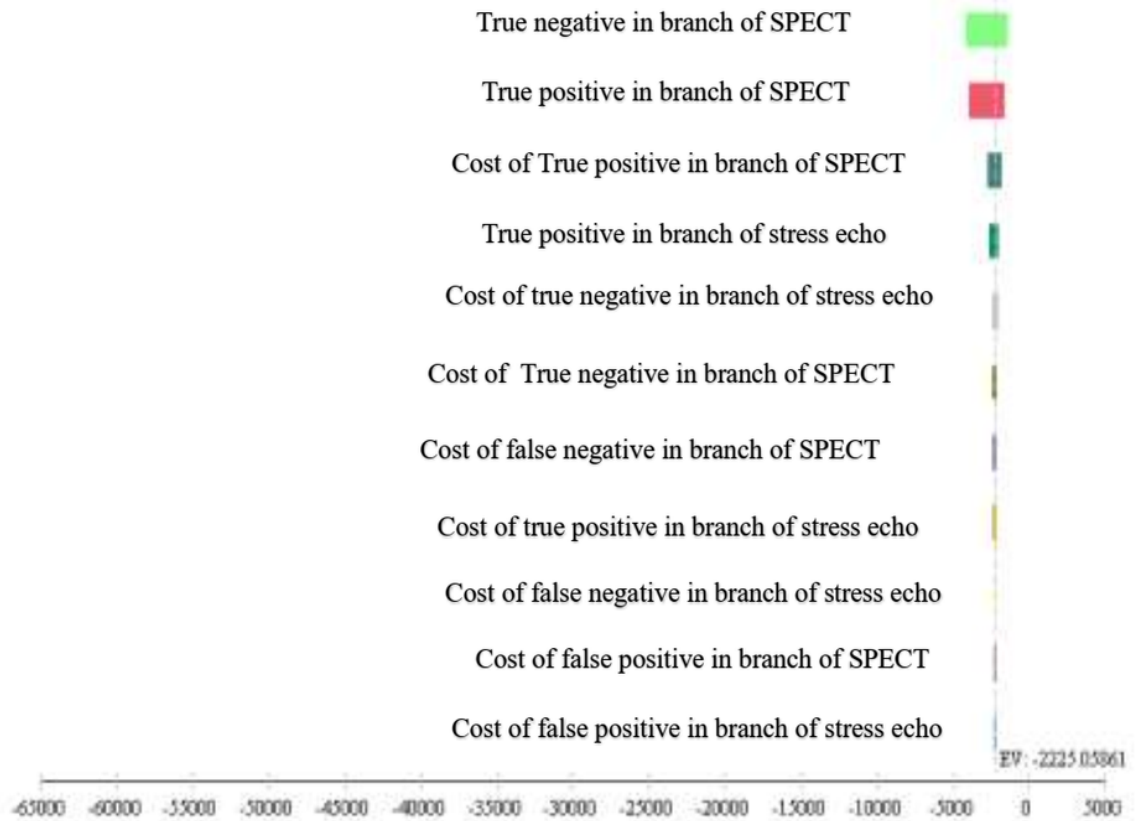


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Tornado diagram for one-way sensitivity analysis

Tornado Analysis (ICER)

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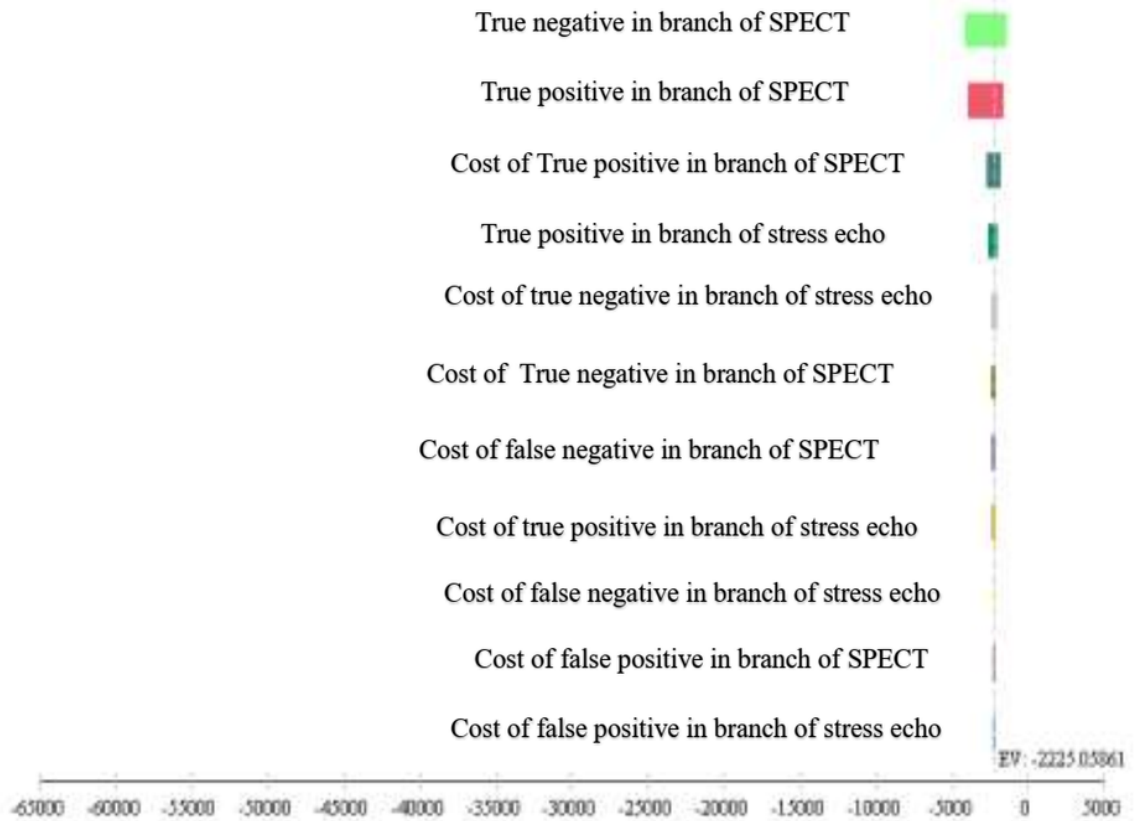


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Tornado diagram for one-way sensitivity analysis