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National Cost Savings From Use of Artificial Intelligence Guided Echocardiography in the Assessment of Intermediate-Risk Patients With Syncope in the Emergency Department

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Abstract

Objectives: Our primary objective was to estimate the realistic impact of an artificial intelligence (AI)-based trans-thoracic echocardiogram (TTE)-first strategy on the annual national cost savings among eligible adult emergency department (ED) patients presenting with syncope in the United States. Our secondary outcomes were the estimated reduction in avoidable ED bed hours and comprehensive TTE studies.

Methods: Using publicly available estimates for inputs such as the size of the adult ED syncope population, typical disposition and risk stratification proportions, and frequency of comprehensive TTE studies, we created a model and ran 1000 trials of a Monte Carlo simulation. Using this simulation, we modeled the national annual cost savings and potential bed hours averted through the impact of avoiding comprehensive TTE studies. We report the descriptive statistics modeling the distribution of all endpoints.

Results: An AI-assisted TTE-first strategy was estimated to save a mean (±SD) of $815 million (±$260 million) by avoiding 468,000 (±141,000) comprehensive TTE studies resulting in 12,500,000 (±4,600,000) bed hours saved.

Conclusion: If adopted widely, an AI-based TTE-first strategy applied to eligible ED patients presenting with syncope could yield substantial benefits by averting avoidable comprehensive TTE studies and saving bed hours.

Keywords: *syncope, echocardiography, cost savings, emergency department, artificial intelligence*

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1 INTRODUCTION

1.1 Background

In the United States, syncope accounts for approximately 3% of emergency department (ED) visits annually and incurs an estimated $2.4 billion in costs for associated hospitalizations.[1,2] Identifying a definitive cause of syncope can be challenging, as potential etiologies are wide-ranging. Given diagnostic uncertainty, clinicians frequently order comprehensive trans-thoracic echocardiograms (TTEs) as part of the evaluation despite the American College of Cardiology and American Heart Association guidelines that advise against the routine use of TTE among patients presenting with syncope.[3] Specifically, TTEs are ordered in up to 90% of patients presenting with syncope, yet in only 3% of patients TTE identifies a structural etiology related to their syncope.[4]

Clinical scoring tools have been created to identify syncope patients who may benefit most from TTE and subsequent admission.[5–7] However, despite this, approximately one-third of syncope patients are still admitted while awaiting TTE, further increasing costs and leading many to question the effectiveness of the new scoring methods.[8] To combat this, alternative diagnostic areas, such as ED observation units, have successfully been used to reduce syncope inpatient admissions.[9]

1.2 Importance

Although primarily indicated in intermediate-risk syncope patients, TTE rates in ED observation units have increased for patients with syncope.[10] In addition, they often are the rate-limiting step to discharge in most of these patients.[11] Regardless, it is believed that intermediate-risk syncope patients who have stable or no known cardiac disease can be safely discharged from the ED.[7] As ED boarding continues to rise and increase mortality,[12,13] new innovative technologies and workflows are sought to improve the timeliness of workups, including syncope.

The application of artificial intelligence (AI) to medical imaging has yielded assistive deep learning software in the field of TTE. Currently, the software allows novices with limited training to obtain diagnostic TTE studies without a significant quality difference compared with trained cardiac sonographers.[14,15] Furthermore, assistive TTE acquisition technology may increase an operator's confidence in their imaging abilities and therefore, use.[16] The scalability of enabling operators with limited training to obtain high-quality TTE images opens up health care to new innovative workflows that may lead to significant cost and time savings.

1.3 Goals of This Investigation

Given the need for innovative solutions to improving ED throughput including timely workups, we aimed to determine the potential benefits of an AI-assisted TTE acquisition software deployed in the ED for patients who present with syncope and otherwise would clinically have a TTE performed. Our primary aim was to estimate the annual number of comprehensive TTEs potentially averted and the associated national cost savings associated with an AI-assistive TTE-first approach for syncope patients hospitalized in observation units. Our secondary aim was to estimate the potential cumulative reduction in ED length of stay. We repeat our analysis at typical annual ED visit volumes to estimate these outcomes at the facility level.

2 MATERIALS AND METHODS

2.1 Study Population and Design

We developed a Monte Carlo simulation model to estimate the annual US national health care cost savings, the cumulative number of comprehensive TTE studies averted, and avoidable hospital bed hours from an AI-assistive TTE-first approach among ED patients with intermediate-risk syncope who require additional cardiac testing at the end of their initial ED evaluation. The study population was evaluated by using publicly available information through literature searches in common databases (Table 1).[17–21] Specifically, high-yield data points were used as inputs and parameters were placed for possible errors as described below. A Monte Carlo simulation runs hundreds of iterations using random values selected from the underlying data distributions for each model input. The results of all iterations are then averaged so that each outcome variable is represented with a distribution, mean, and SD of the final estimate, accounting for the uncertainty of the model inputs (Table 1).[17–21]

We ran a standard 1000 model iterations using input parameters derived from the most recently available data distributions in the literature and other authoritative sources (eg, the National Hospital Ambulatory Care Survey administered via the US Centers for Disease Control and Prevention) (Fig 1). We assumed a 10% relative SD for input estimates when not otherwise specified, with a lower and upper bound of 0% and 100% for percentages. We assumed a normal distribution for all inputs with reported SD. However, we assumed a BetaPERT (Beta Program and Evaluation Review Technique) distribution for inputs associated with an IQR or 95% CI. BetaPERT distributions are smooth distributions characterized by minimum, most likely, and maximum values.[22,23] This modeling technique is ideal for estimating the completion time of an event, with a known best estimate for the minimum, maximum, and most likely outcomes. Accordingly, they are most appropriate for describing variables with a reported range of values. This study analyzed publicly available data without using Protected Health Information and was exempt from institutional board review at our institution.

The Bottom Line

Patients with syncope deemed intermediate risk are often hospitalized while waiting for a trans-thoracic echocardiogram (TTE). As emergency department (ED) boarding has increased, quicker discharges for specific subgroups of patients has become necessary including intermediate-risk syncope patients. The advent of an artificial intelligence-assisted TTE strategy if implemented could result in faster dischargers leading to ED bed hours saved and significant cost savings for an ED. As the cardiac sonographer shortage widens, all strategies that minimize avoidable comprehensive TTEs are needed.

2.2 Annual Number of Comprehensive TTEs Averted

We used the most currently available references to estimate the percentage (and thus annual visit volume, based on currently available overall ED visit volumes) of patients presenting to the ED in the United States with syncope. Given a range of 1% to 3% of ED visits, we chose a BetaPERT distribution to best represent the underlying data for the input variable of visits for syncope.[17] Furthermore, we leveraged prior investigations that included risk stratification of patients presenting to the ED with syncope to determine the size of the population at intermediate risk, most likely to be hospitalized in observation status for further diagnostic testing, such as a comprehensive TTE.[11] We assumed low-risk patients could be discharged without further testing or receive an outpatient TTE postdischarge (eg, patients with a clear vasovagal or orthostatic hypotension history without red flag examination or diagnostic findings in the ED). In contrast, we assumed high-risk patients (eg, those with a history of ventricular arrhythmias or ED evaluation consistent with a dangerous cause of syncope, such as gastrointestinal bleeding) would need inpatient admission regardless of AI-assistive TTE use.

2.3 Reduction in Hospital Bed Hours

After estimating the annual volume of avoidable comprehensive TTEs, we used that value to calculate the annual reduction in hospital bed hours. We assumed a baseline hospital length of stay for target patients for this intervention to be 28.2 hours.[21] Furthermore, we chose a length of stay of 1.2 hours for those patients with an AI-assistive TTE and a reassuring result that would permit an immediate discharge.[21] We assumed an underlying Poisson distribution for our length of stay input variables to best reflect the underlying data.[24]

2.4 Annual Cost Savings

We used point estimates without an underlying distribution informed by the 2024 national Medicare payments (Medicare Administrative Contractor 0000000) as a cost proxy, consistent with previous cost savings analyses.[9] We chose not to use charges due to wide variability and low correlation with actual payments. We assumed that target patients hospitalized for a comprehensive TTE would be billed in observation status, with facility charges determined by APC 8011, which would be avoided for those eligible for early discharge.

2.5 Secondary Analysis

We reran the model for typical annual adult ED visit volumes: 30,000. 60,000, and 90,000. As a result, our results can better inform facility-level benefits to offset the expected cost of acquisition, education, and other work needed to adopt this new strategy and permit a return on investment analysis.

2.6 Sensitivity Analysis

Due to the lack of a reliable and available estimate of the proportion of ED syncope patients not undergoing further cardiac diagnostics for whom an unremarkable TTE result would permit an immediate discharge, we assumed a value of 90% in our base case. This was chosen as an average value between sources, suggesting the value was between 81% and 97%.[25] We performed a sensitivity analysis around this value and reported primary and secondary outcomes at the lower rate of 20%. Other model inputs were well-referenced without a wide distribution of possible values, excluding them from impacting our model outcomes in a sensitivity analysis.

2.7 Statistical Analysis

We used Crystal Ball (Release 11.1.2.4, Oracle Corporation) for our analysis. We assumed a normal distribution for all inputs with reported means with associated SD except for those with a BetaPERT distribution as previously described.

3 RESULTS

3.1 Main Model Outputs

3.1.1 National estimates

We found that an AI-assistive TTE-first strategy was estimated to save a mean (±SD) of $815 million (±$260 million) by avoiding 468,000 (±141,000) comprehensive TTE studies, resulting in 12,500,000 (±4,600,000) bed hours saved annually. We illustrate distributions of the model iterations for cost savings, avoided comprehensive TTE studies, and bed hours saved in Figure 2A-C, respectively.

3.1.2 Facility-level estimates

To examine the facility-level impact of an AI-assistive TTE-first approach for eligible patients with syncope, we repeated the analysis for typical annual adult ED visit volumes and reported the

TABLE 1. Model inputs.

	Description	Value	SD, SE, or 95% CI	Distribution type	Source	Reference
	Annual number of US ED visits (total)	139,000,000	10,000,000 SE	Normal	NHAMCS 2021	NHAMCS[17]
A	Annual number of US ED visits syncope (age ≥18 y)	2%	Minimum 1%, maximum 3%	BetaPERT	National Hospital Ambulatory Medical Care Survey (2010-2015)	Probst et al[18]
B	Percentage of ED syncope that is hospitalized in observation status (intermediate risk)	31.8%	Relative 5% SD	Normal	Retrospective single center study 2012	Anderson et al[11]
C	Percentage of ED observation patients with syncope that receives a TTE	60%	Relative 20% SD	Normal	Multicenter RCT 2013	Sun et al[9]
D	Percentage of negative TTE findings that leads to discharge	90%	Relative 10% SD	Normal	Multicenter retrospective study 2019	Ghani et al[19]
E	Percentage of positive TTE cases requiring positive TTE	13.3%	Relative 5% SD	Normal	Retrospective single center study 2012	Anderson et al[11]
F	Percentage of negative TTE requiring alternative testing	40%	Relative 20% SD	Normal	Retrospective single center study 2012	Anderson et al[11]
G	Medicare reimbursement for complete TTE (CPT 93306)	$199	N/A	N/A	CMS Medicare Physician Fee Schedule 2024	CMS[20]
H	Medicare reimbursement for Limited TTE (CPT 93308)	$100	N/A	N/A	CMS Medicare Physician Fee Schedule 2024	CMS[20]
I	Medicare reimbursement for ED observation (APC 8011)	$2283	N/A	N/A	CMS Medicare Physician Fee Schedule 2024	CMS[20]
J	Length of stay in ED for patients with formal TTE in hours	28.2 h	Low cutpoint = 5 h, high cutpoint = 48 h	Poisson	Prospective single center study 2020	Benbarkat et al 2020[21]
K	Length of stay in ED for patients with AI-assistive TTE in hours	1.17 h	Low cutpoint = 0.5 h, high cutpoint = 3 h	Poisson	Prospective single center study 2020	Benbarkat et al 2020[21]

AI, artificial intelligence; APC, Ambulatory Payment Classification; CMS, Centers for Medicare & Medicaid Services; CPT, Current Procedural Terminology; ED, emergency department; TTE, trans-thoracic echocardiogram.

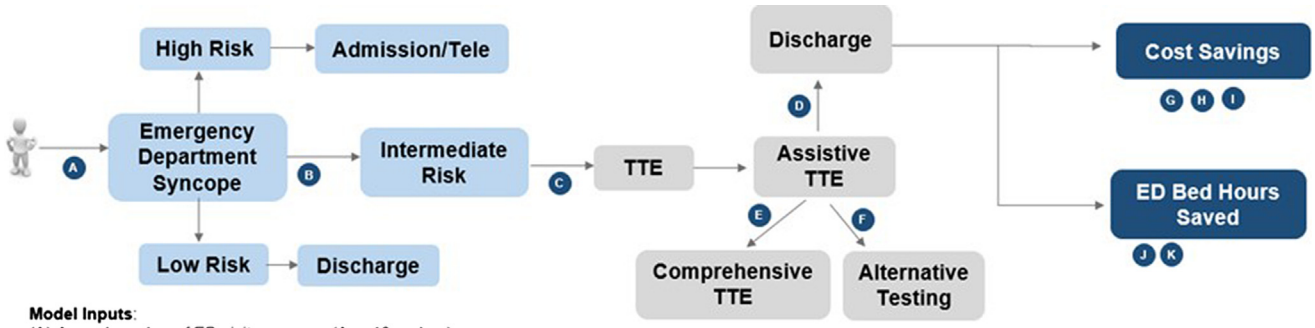
results in Table 2. At 30,000 annual visits, an AI-assistive TTE-first strategy was estimated to save a mean (±SD) of $180,145 (±$58,879) by avoiding 104 (±32) comprehensive TTE studies, resulting in 2758 (±975) bed hours saved. At 60,000 annual visits, an AI-assistive TTE-first strategy was estimated to save a mean (±SD) of $363,373 (±$115,682) by avoiding 207 (±63) comprehensive TTE studies, resulting in 5572 (±2055) bed hours saved. Finally, at 90,000 annual visits, an AI-assistive TTE-first strategy was estimated to save a mean (±SD) of $542,348 (±$173,170) by avoiding 320 (±93) comprehensive TTE studies, resulting in 8249 (±2940) bed hours saved.

3.2 Sensitivity Analysis

We reduced the key assumption that TTE is the rate-limiting step to discharge home to 20%, lowering the national cost savings to $183 million (±$60 million) annually.

3.3 Limitations

Our analysis was a simulation model; thus, it was limited by the model inputs and structure accuracy. We employed Monte Carlo methods to better account for uncertainty in our inputs and informed our model variables using the most recent and widely accepted sources. However, we also had to make assumptions and adjustments regarding model inputs when data were unavailable. Importantly, we did not account for AI-assisted TTE equipment acquisition, maintenance costs, and staff training expenses related to AI-TTE image acquisition. However, we suspect many of these costs are similar if not less than



Model Inputs:
(A) Annual number of ED visits syncope (Age 18 and up)
(B) Percentage of ED syncope that is Admitted to ED Observation (Intermediate Risk)
(C) Percentage of ED Obs patients with syncope that obtain TTE
(D) Percentage of Negative TTE Findings that lead to discharge
(E) Percentage of Positive TTE Cases requiring positive TTE
(F) Percentage of negative TTE requiring Alternative Testing
(G) Medicare reimbursement for Complete TTE (CPT 93306)
(H) Medicare reimbursement for Limited TTE (CPT 93308)
(I) Medicare Reimbursement for Observation visit vs ED Obs
(J) Length of Stay in ED for patients with Formal TTE in minutes
(K) Length of Stay in ED for patients with Assistive TTE in minutes

Model Outputs:
1. Annual Number of Formal TTE Averted (18 up) = (A*B*C)-(A*B*C*(1-D))
2. Annual Cost Savings from Averted Formal TTE (18 up) = ((A*B*C)-(A*B*C*(1-D)))*((1-F)+E)*(G-H)+((A*B*C)-(A*B*C*(1-D)))*((1-F)+E)*I
3. Annual Cumulative Reduction in ED Bed Hours = ((A*B*C)-(C*(1-D)))*(J-K)

FIGURE 1. Monte Carlo model. CPT, Current Procedural Terminology; ED, emergency department; TTE, trans-thoracic echocardiogram.

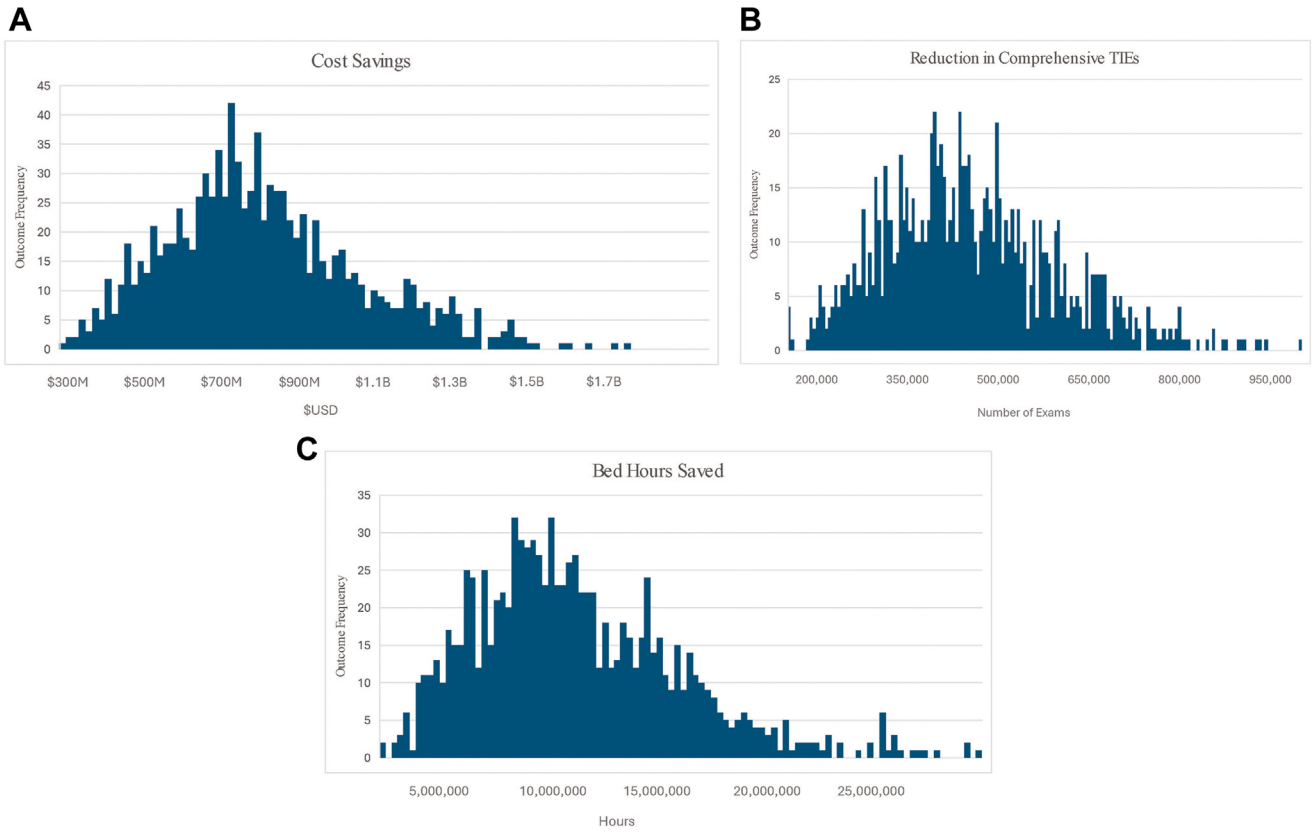


FIGURE 2. Monte Carlo outputs demonstrating (A) national cost savings from AI-TTE use in syncope, (B) national avoided comprehensive TTE studies from AI-TTE use in syncope, and (C) national reduction in hospital bed hours from AI-TTE use in syncope. AI, artificial intelligence; TTE, trans-thoracic echocardiogram.

TABLE 2. Model outputs at typical emergency department volumes.

Annual adult ED visits	Annual cost savings ($ ±SD)	Annual avoided TTE studies (SD)	Annual bed hour reduction (SD)
30,000	$180,329 ± $14,356	108 ± 8	2785 ± 241
60,000	$359,712 ± $28,287	206 ± 15	5573 ± 472
90,000	$539,132 ± $41,712	309 ± 23	8336 ± 720

ED, emergency department; TTE, trans-thoracic echocardiogram.

costs associated with alternative diagnostic solutions such as use of point-of-care cardiac ultrasound. With most new technologies, development costs can be indirectly passed on to users via fees associated with product use. Although for AI-assisted technologies this may manifest in the device costs to the hospital, this will have to be assessed on a per device basis. Finally, we represent cost savings as avoidable health care expenses, which may be best realized in an accountable care organization or global budget framework; in a fee-for-service environment, hospitals may less directly capture cost savings. However, safely reducing bed hours is still highly valuable in capacity-constrained systems as well as the possibility for additional testing.

4 DISCUSSION

In this analysis, we created a model using input variables from multiple literature sources showing significant potential national cost savings and reduction in use of hospital resources from use of AI-assisted TTE in patients presenting to the ED with syncope. Prior investigations have demonstrated that TTE is highly likely to be the rate-limiting step of disposition for the majority of patients with syncope already admitted to ED observation.[11] Although no workflow for such AI-based technologies currently exists, the benefit of obtaining earlier diagnostic information using resources already present in the ED to deploy such technologies is not only desired but, as shown in our study, can substantially reduce cost and time.

Previously, significant cost savings have been demonstrated by shifting intermediate-risk syncope hospitalizations into ED observation units.[26] Although innovative and financially beneficial at the time, new data suggest that admission to any unit may not be necessary for select patients classified as intermediate- risk.[7,11] Despite this, risk stratification has not successfully impacted the discharge rate for this patient population.[27] Challenges with culture change associated with health care workers comfort with decreased diagnostic testing may be contributing to this trend. Our study highlights how technology can be integrated into ED workflows to impart cost savings, improve throughput, and potentially leading to more expedited discharges from the ED through faster TTEs.

AI tools are rapidly being developed for deployment across medical settings, with 2 of the top 3 AI-specific Current Procedural Terminology codes dedicated to coronary artery disease.[28] Unlike our proposed workflow, AI-associated workflows (ie, AI-driven fractional flow reserve computed tomography) in cardiology have already made their way into the 2021 guidelines for the evaluation of chest pain.[29] Future studies examining the function of our proposed workflow and actual associated cost savings will need to be directly observed in patient care settings.

AI-assistive TTE technology may not only benefit ED patients but also may benefit many different areas of health care. The increased need for ultrasound examinations has significantly outpaced the number of trained sonographers, leading to a significant resource national shortage.[30] It is reasonable to assume that obtaining routine hospital-based TTEs is experiencing delays, which may translate into increased length of stay in hospitalized patients. New workflows incorporating AI-assistive TTE can be performed by novices during routine screening within medical offices, in intensive care units for targeted diagnostic questions, with hospitalists evaluating cardiac changes over time, and many others may start to take shape to combat this shortage. This technology becomes more scalable when limited training is needed for diagnostic-quality TTE images. Future studies examining each unique workflow will be required to assess efficacy and safety.

If adopted widely, an AI-assistive TTE-first strategy applied to eligible ED patients with intermediate-risk syncope could yield substantial benefits by averting avoidable comprehensive TTE studies, obtaining more rapid diagnostic information, and saving admission bed hours. Given the high negative rate of TTE in syncope, an AI-assistive device that obtains images faster and with high quality could provide new efficient and effective workflows in the ED that may be extrapolated to other health care settings.

AUTHOR CONTRIBUTIONS

AG and CB conceived and designed the study. AG, ND, SC and CB drafted the manuscript. All authors contributed to critical revision of the manuscript. AG and CB take responsibility for the manuscript as a whole.

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UltraSight Inc (Cambridge) sponsored and funded the analysis.

CONFLICT OF INTEREST

Dr Baugh is a speaker for Roche Diagnostics and has previously participated in Roche, Salix Pharmaceuticals, Pfizer Inc, and AstraZeneca advisory boards, consults for Abbott

Laboratories, Roche, and Pfizer Inc, and is an advisor to Lucia Health Guidelines. Dr Goldsmith is a consultant for UltraSight Inc, Butterfly, and Exo.

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