


Original Article

The Utility of Echocardiogram in the Workup of Ischemic Stroke Patients

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ABSTRACT: Background: Cardiac sources of emboli can be identified by transthoracic echocardiogram (TTE). The Canadian Best Practice Guidelines recommend routine use of TTE in the initial workup of ischemic stroke when an embolic source is suspected. However, TTEs are commonly ordered for all patients despite insufficient evidence to justify cost-effectiveness. We aim to evaluate the TTE ordering pattern in the initial workup of ischemic stroke at a regional Stroke Center in Central South Ontario and determine the proportion of studies which led to a change in management and affected length of stay (LOS). **Methods:** Hospital records of 520 patients with a discharge diagnosis of TIA or ischemic stroke between October 2016 and June 2017 were reviewed to gather information. **Results:** 477 patients admitted for TIA or ischemic stroke met inclusion criteria. 67.9% received TTE, out of which 6.0% had findings of cardiac sources of emboli including left ventricular thrombus, atrial septal aneurysm, PFO, atrial myxoma, and valvular vegetation. 2.5% of all TTE findings led to change in medical management. The median LOS of patients who underwent TTE was 2 days longer ($p < 0.00001$). **Conclusion:** TTE in the initial workup of TIA or ischemic stroke remains common practice. The yield of TTEs is low, and the proportion of studies that lead to changes in medical management is minimal. TTE completion was associated with increased LOS and may result in increased healthcare spending; however, additional factors prolonging the LOS could not be excluded.

RÉSUMÉ : *L'utilité des examens d'échographie cardiaque dans le bilan de patients victimes d'un AVC ischémique. Contexte :* Les sources cardiaques d'embolies peuvent être identifiées par un examen d'échographie cardiaque transthoracique (ECTT). À ce sujet, les lignes directrices canadiennes en matière de pratiques exemplaires recommandent l'utilisation systématique de la technique d'ECTT dans le bilan initial d'un patient victime d'un AVC ischémique lorsqu'une source de nature embolique est suspectée. Cependant, les examens d'ECTT demeurent couramment prescrits pour tous les patients, et ce, malgré l'insuffisance de données probantes justifiant leur rentabilité. Notre objectif est ici d'évaluer dans un centre régional de traitement des AVC du centre-sud de l'Ontario le modèle de prescription des ECTT dans le bilan initial de patients victimes d'un AVC ischémique et de déterminer la proportion d'études qui ont conduit à un changement de prise en charge des patients et ont affecté la durée de leur séjour. **Méthodes :** Les dossiers hospitaliers de 520 patients victimes d'un accident ischémique transitoire (AIT) ou d'un AVC ischémique et ayant obtenu leur congé entre octobre 2016 et juin 2017 ont été analysés pour recueillir des renseignements. **Résultats :** Au total, 477 patients admis en raison d'un AIT ou d'un AVC ischémique ont répondu à nos critères d'inclusion. À noter que 67,9 % d'entre eux ont subi un examen d'ECTT ; parmi ces derniers, on a découvert chez 6,0 % d'entre eux des sources cardiaques d'embolie, notamment un thrombus ventriculaire gauche, un anévrisme du septum interauriculaire, un foramen ovale perméable (FOP), un myxome auriculaire et une végétation valvulaire. Enfin, 2,5 % des résultats d'ECTT ont conduit à un changement de traitement médical alors que la durée médiane de séjour des patients ayant bénéficié d'un examen d'ECTT était plus longue de 2 jours ($p < 0,00001$). **Conclusion :** Le recours à l'ECTT dans le bilan initial d'un AIT ou d'un AVC ischémique reste une pratique courante. Cela dit, le rendement des examens d'ECTT est faible et la proportion d'études qui ont débouché sur des changements dans la prise en charge médicale des patients est minime. De plus, la réalisation d'un examen d'ECTT est associée à une augmentation de la durée de séjour des patients et peut entraîner une augmentation des dépenses de santé. On ne peut exclure toutefois qu'il existe d'autres facteurs prolongeant la durée des séjours.

Keywords: Stroke; Echocardiography

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Introduction

Stroke imposes a significant economic burden on the healthcare system. The average cost per-person for a stroke admission in Canada is over \$50,000, which is higher than the average cost of care for people in the first year after a diagnosis of cancer (\$25,914) or coronary artery disease (\$23,000–26,000).¹ Relevant testing to identify stroke etiology is crucial to inform appropriate management in secondary stroke prevention. A transthoracic echocardiogram (TTE) is a routine investigation in the workup of cerebrovascular ischemia. TTE is often used to identify cardioembolic sources of stroke (patent foramen ovale (PFO), left ventricular thrombus, and atrial fibrillation (AF), among others) which account for approximately 15–30% of cases. When identified, these etiologies often warrant anticoagulation.² The most common cardioembolic cause, AF, is often diagnosed on electrocardiogram³ or Holter monitoring,⁴ while an intra-cardiac thrombus is found almost exclusively in patients with clinical evidence of ischemic heart disease, but can be rare even in such instances⁵. Positive findings on TTE therefore seldom lead to a change in management as patients may have already met criteria for anticoagulation. As such, the current 2020 Canadian Stroke Best Practices guidelines suggest reserving TTE for patients where a cardioembolic or paradoxical embolic source is suspected or in cases of embolic stroke of undetermined source.⁶ In contrast, the 2021 American Heart Association/American Stroke Association (AHA/ASA) recommend TTE for all patients once ischemic stroke is confirmed on neuroimaging.⁷

The current practice at Hamilton General Hospital is for patients with stroke to receive a TTE initially, followed by transesophageal echocardiogram (TEE) if TTE is non-diagnostic but a cardioembolic source is strongly suspected. Agitated saline injections can increase the yield of transthoracic studies by 15% in patients known to have cardiac disease⁸ but TEE is superior in detecting left atrial thrombi, PFO, cardiac tumors and native or prosthetic valve disease.² TEE has also been found to lead to a change in medical management in approximately 14–17% of patients with suspected embolic stroke.^{9,10} Other modalities such as cardiac CT and cardiac MRI may also be considered,^{7,11} but are currently less commonly pursued.

In 2014, the Canadian Agency for Drugs and Technologies in Health completed a review on the cost-effectiveness of echocardiography in patients with ischemic strokes. The yield of TTEs in determining the cardiac sources of emboli ranged from 6.5 to 25%, but this only resulted in a change in clinical management in 0–5% of cases.¹¹ With concerns of high healthcare costs, prudent stroke workup should be tailored to each individual patient, their presentation, and their medical history.

The goal of this study is to explore routine TTE ordering practices for admitted patients with ischemic stroke and TIA at Hamilton General Hospital. We also seek to determine the proportion of echocardiograms that lead to changes in patient management and assess whether these investigations prolong hospital admissions.

Methods

Study Design and Participants: This study was approved by the Hamilton Integrated Research Ethics Board. Our cohort included consecutive patients discharged from Hamilton General Hospital (Hamilton, Ontario, Canada) between October 2016 and June

2017 with a diagnosis of TIA or ischemic stroke. The Hamilton General Hospital is one of the region's comprehensive stroke centers and services a diverse population of over 2 million people in Central South Ontario.¹² Patient with cerebrovascular ischemia as a diagnosis most responsible for admission received comprehensive, multidisciplinary care led by vascular neurologists on our dedicated stroke unit. Patients with intracerebral hemorrhage, those who had a more likely alternate diagnosis (e.g., migraine or seizure), or those admitted multiple times with a diagnosis of TIA or ischemic stroke within the study period were excluded.

Regarding our length of stay (LOS) analysis, patients with an identifiable factor other than uncomplicated, stroke admission-related care, which would potentially prolong or abbreviate the calculated LOS were excluded. This was inclusive of initial transfer from another hospital, repatriation to a peripheral hospital, palliation, death, early discharge from hospital against medical advice, other medical comorbidities prolonging LOS, clinical status changed to "alternate level of care" in waiting for appropriate disposition, and re-admissions from rehabilitation. Where unforeseen factors affecting LOS were identified, the reviewers were required to discuss the circumstance to achieve consensus for exclusion.

Data Collection: The Canadian Institute for Health Information Discharge Abstract Database (DAD) was used to identify patients within our study setting for review. Patients who had TIA or ischemic stroke listed as the diagnosis most responsible for admission on their discharge summary were selected (diagnoses are recorded in the DAD using *International Classification of Diseases and Related Health Problems, 10th Revision* (ICD-10) diagnostic criteria codes). Five reviewers (L.V., M.G., M.D., R.X., A.B.) performed manual data extraction from eligible patient charts. This included patient characteristics (age, sex, previous history of congestive heart failure (CHF), coronary artery disease (CAD), myocardial infarction (MI), TIA/ischemic stroke, AF, and current use of anticoagulation), details of the patient's course in hospital (dates of admission, investigations, discharge, and LOS) as well as pertinent test results from echocardiographic studies. Throughout the data collection process, patients were selected at random for repeat chart review to verify correct extraction of data, and discrepancies were discussed between reviewers until consensus was achieved. Patients with prolonged lengths of stay without an identifiable documented reason were included for analysis.

Study Outcomes: The primary outcome of this study was the number and proportion of patients with a clinically actionable finding on TTE (i.e., one that influenced secondary stroke management). Secondary outcomes include (1) demographic and health characteristics of those with clinically actionable findings to assess for comorbidities that may predict increased utility in testing, (2) the number of negative TTEs completed which were followed by TEE with positive findings, (3) the mean LOS in patients with and without TTE, and (4) the number of days patients were discharged post-TEE.

Statistical Analysis: Descriptive statistics were completed on patient characteristic data (e.g., age, sex, medical history, and anticoagulation use) as well as transthoracic, transesophageal, and bubble study findings. A Kruskal–Wallis test was performed to compare medians between groups. Statistical analyses were performed in Microsoft Excel. A *p*-value of <0.05 was considered significant.

Table 1: Study participant characteristics

Patient Characteristics	Stroke	TIA	No echocardiography	TTE	TEE
No. (%)	442 (92.7%)	35 (7.3%)	153 (32.1%)	324 (67.9%)	14 (2.9%)
Male Sex (%)	238 (53.8%)	22 (62.9%)	75 (49.0%)	185 (57.1%)	9 (64.3%)
Mean Age (year, ± SD)	70.9 (± 14.3)	75.2 (± 11.6)	71.5 (± 14.1)	71.1 (±14.3)	53.9 (± 13.8)
Relevant PMH (%)					
AFIB	75 (17.0%)	9 (25.7%)	37 (24.2%)	47 (14.5%)	0
CHF	38 (8.6%)	4 (11.4%)	11 (7.2%)	31 (9.6%)	0
CAD	79 (17.9%)	12 (34.3%)	34 (22.2%)	57 (17.6%)	1 (7.1%)
Previous MI	56 (12.7%)	6 (17.1%)	19 (12.4%)	43 (13.3%)	0
Previous TIA	35 (7.9%)	8 (22.9%)	11 (7.2%)	32 (9.9%)	1 (7.1%)
Previous Stroke	60 (13.6%)	10 (28.6%)	32 (20.9%)	38 (11.7%)	0
Previous AC use	66 (14.9%)	9 (25.7%)	34 (22.2%)	41 (12.7%)	1 (7.1%)

TTE = transthoracic echocardiograph, TEE = transesophageal echocardiogram, SD = standard deviation, PMH = past medical history, AFIB = atrial fibrillation, CHF = congestive heart failure, CAD = coronary artery disease, MI = myocardial infarction, TIA = transient ischemic attack, AC = anti-coagulant.

Table 2: Echocardiography findings related to cardioembolic sources of stroke/TIA

Findings	TTE			TEE	
	No. (% total TTE)	No. change in management	No. false negatives ^a	No. (% total TEE)	No. change in management
Atrial myxoma	1 (0.3%)	1	–	1 (7.1%)	–
Valvular vegetations	1 (0.3%)	1	1	2 (14.3%)	1
Left atrial thrombus	0	–	–	0	–
Left ventricular thrombus	5 (1.5%)	5	–	0	–
Left ventricular aneurysm	0	–	–	0	–
Inter-atrial septal aneurysm	4 (1.2%)	–	–	0	–
Patent Foramen Ovale	4 (1.2%)	1	3	5 (35.7%)	–
Bubble Study ^b	2 (0.6%)	–	3	4 (28.6%)	–
Total (% total TTE or TEE)	14 (6.0%) ^c	8 (2.5%)	4	8 (57.1%)	1 (7.1%)

TTE = transthoracic echocardiograph, TEE = transesophageal echocardiogram, No. = number.

^aTTE results that differ from TEE results presented.

^bPatient foramen ovale specified to have been found on bubble studies are inclusive of PFO count listed in the column above.

^cOne patient with both atrial septal aneurysm and PFO is counted once in the calculated total.

Results

The charts of 520 patients were reviewed, of which 477 were confirmed to be admitted for ischemic stroke (442, 92.7%) or TIA (35, 7.3%). 324 (67.9%) and 14 (2.9%) of these patients received TTE and TEE, respectively, while 153 (32.1%) did not undergo echocardiographic investigations at all (Table 1). 21% of patients who had undergone echocardiography had a history of prior stroke or TIA, while 40.5% of patients had a history of CAD, previous MI, or CHF. 47 (14.5%) patients who underwent TTE were previously known to have AF, and 41 (12.7%) patients were previously on anticoagulation therapy (Table 1).

Of the 324 patients who underwent TTE investigation, 14 (6.0%) had findings of cardiac sources of emboli: 5 (1.5%) patients with left ventricular thrombus, 4 (1.2%) patients with atrial septal aneurysm, 4 (1.2%) patients with a PFO, 1 (0.3%) patient with atrial myxoma, 1 (0.3%) patient with valvular vegetation (Table 2). No patients were found to have a left atrial thrombus or left ventricular aneurysm. 18 bubble studies in total were performed. Two out of four TTEs with positive results for PFO were completed with bubble studies. 2.5% of all TTE findings

Table 3: Median length of stay for all patients with or without echocardiography

	With TTE (n = 199)	Without TTE (n = 63)	p-value
Median LOS (days [IQR])	4 [3–6]	2 [1–3]	<0.00001
Median time from admission to TTE (days [IQR])	2 [1–3]	–	–
Median time from TTE to discharge (days [IQR])	1 [0–3]	–	–
No. (%) of patients discharged			
On the day of TTE	60 (30.2%)	–	–
1 day after TTE	46 (23.1%)	–	–
2–4 days after TTE	70 (35.2%)	–	–
>5 days after TTE	23 (11.6%)	–	–

led to changes in medical management. This included the initiation or change of anti-coagulant therapy in five patients found to have a left ventricular thrombus, specialist consultation in two patients

Table 4: Median length of stay for TIA versus ischemic stroke patients with or without echocardiography

	TIA (n = 30)			Stroke (n = 232)		
	With TTE (n = 14)	Without TTE (n = 16)	p-value	With TTE (n = 185)	Without TTE (n = 47)	p-value
Median LOS (days [IQR])	3 [2–4]	2 [1–2]	0.04831	4 [3–6]	2 [1–4]	<0.00001
Median time from admission to TTE (days [IQR])	1 [1–2]	–	–	2 [1–3]	–	–
Median time from TTE to discharge (days [IQR])	0.5 [0–2.75]	–	–	1 [0–3]	–	–
No. (%) of patients discharged						
On the day of TTE	7 (50%)			53 (28.6%)		
1 day after TTE	2 (14.3%)	–	–	44 (23.8%)	–	–
2–4 days after TTE	3 (21.4%)			67 (36.2%)		
>5 days after TTE	2 (14.3%)			21 (11.4%)		

TIA = transient ischemic attack, TTE = transthoracic echocardiograph, TEE = transesophageal echocardiogram, LOS = length of stay, IQR = interquartile range.

for atrial myxoma and valvular vegetations, and surgical PFO closure for one patient (Table 2). Of note, no patients with newly identified left ventricular thrombus had a previous history of, or were newly diagnosed with AFIB during their admission. One patient with left ventricular thrombus was poorly compliant on warfarin for history of left ventricular thrombus.

A total of 14 patients underwent TEE, of which 8 (57.1%) had findings of cardiac sources of emboli: 5 (35.7%) patients were found to have a PFO, 2 (14.3%) patients had valvular vegetations, and 1 (7.1%) patient had an atrial myxoma (Table 2). Four out of five TEEs with positive results for PFO were completed with bubble studies. Three new findings of PFO and one case of valvular vegetations were seen on TEE but not on TTE. The single case of valvular disease led to a change in management (Table 2).

In our LOS analysis, 262 patients met inclusion criteria (Supplementary Figure 1). 88 patients were excluded for hospital transfers and repatriations, 55 for in-hospital mortality, 38 for medical comorbidities prolonging LOS, 11 for transition to alternative level of care, 7 for patients leaving against medical advice, and 6 patients for transitions to palliative care.

199 patients (75.9%) underwent TTE. The median LOS for patients who received a TTE was 4 days (IQR 3–6), while patients who did not receive a TTE were admitted for a median LOS of 2 days (IQR 1–3). Patients who underwent TTE had a significantly longer LOS by approximately 2 days (IQR 1–3) ($p < 0.00001$, Table 3). Upon stratification by diagnosis, 185 (79.7%) patients diagnosed with ischemic stroke who received a TTE had a significantly longer median LOS compared to those who did not (4 days (IQR 3–6) vs. 2 days (IQR 1–4), $p < 0.00001$, Table 4). By comparison, 14 (46.7%) patients diagnosed with TIA who underwent TTE also had a longer median LOS compared to those who did not (3 days (IQR 2–4) vs. 2 days (IQR 1–2), $p = 0.04831$, Table 4). Half (50%) of the patients with TIA were discharged on the day of their TTE in comparison to 28.6% of patients with ischemic stroke (Table 4). In contrast, a higher proportion of patients with ischemic stroke were discharged 1–4 days following TTE compared to patients with TIA (1 day post-TTE 23.8% vs. 14.3%, 2–4 days post-TTE 36.2% vs. 21.4%).

Discussion

We have demonstrated that approximately 70% of patients admitted with TIA or ischemic stroke at Hamilton General Hospital will undergo transthoracic echocardiographic studies, out of which 85% will yield normal results. Although this is in

keeping with the general yield of cardiac echocardiography in stroke workup at other institutions in Ontario,¹³ only 2.5% of all TTEs demonstrated clinically actionable results and change in patient care. Other studies have found similar rates of therapeutic yield.^{2,14} Furthermore, although over 50% of TEE performed found evidence of cardiac source of emboli, the added diagnostic yield of these studies was minimal, as they often followed a positive transthoracic study and were only confirmatory. A recent study by Rinkel et al. has demonstrated the diagnostic utility of ECG-gated cardiac CT in detecting cardiac thrombi in stroke patients.¹⁵ Cardiac CT offers a less invasive alternative to TEE. It could likely be used as adjunct testing in patients with strong suspicion for cardioembolic stroke, but this would not eliminate the need for echocardiography if PFO or hypokinetic heart disease is suspected. Studies on the relative cost-effectiveness of this modality compared to echocardiography and the general feasibility in acute stroke workup are also needed.

TTE completion was associated with a median two-day increase in LOS compared to patients who did not undergo imaging. Our findings are consistent with the study by Fralick et al.¹³ where the average LOS increased by 3 days in ischemic stroke patients who received TTE. Although causality cannot be ascertained, these data suggest that more selective use of TTE in acute stroke and TIA patients may help reduce LOS. As discussed previously, the cost of stroke admissions impose significant economic burden on the healthcare system.¹ Studies suggest that reductions in LOS by even half of a day could have significant economic impacts.¹⁶ Our study suggests that avoiding indiscriminate use of cardiac investigations may reduce the economic impact of stroke on society.

Our study was restricted by its small sample size from a single center. It is also difficult to generalize our findings to younger populations with stroke, as this group was underrepresented in the current study sample, where screening for PFO and other cardiac causes of stroke may be of more significant clinical importance.

Conclusion

In summary, TTE is commonly used in the initial workup of TIA and ischemic stroke at Hamilton General Hospital, despite current recommendations on practice and relatively low return of actionable findings. TTE completion is also associated with prolonged LOS, which may result in increased healthcare spending. Further cost-effectiveness studies are needed to ascertain the value of other imaging modalities when investigating cardiac sources of emboli to guide optimal ordering practices.

Supplementary Material. To view supplementary material for this article, please visit <https://doi.org/10.1017/cjn.2023.11>.

Statement of Authorship. All authors have read and approved the content of the manuscript. The authors accept accountability for all aspects of the work. L.A.V., M.D., M.G., A.B., and R.X contributed to chart review and writing of the manuscript. Statistical analysis was performed by L.A.V., A.B., and N.P. Finally, K.P. was the supervisor for this study and provided guidance at all levels.

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