EVALUATION OF THE IMPLEMENTATION OF A REAL TIME ELECTRONIC TRIAGE DECISION-SUPPORT TOOL (eCTAS) IN ONTARIO EMERGENCY DEPARTMENTS

EVALUATION OF THE IMPLEMENTATION OF A REAL TIME ELECTRONIC TRIAGE DECISION-SUPPORT TOOL (eCTAS) IN ONTARIO EMERGENCY DEPARTMENTS

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ABSTRACT

Triage is a fundamental process for the safe and efficient management of patients where health care demands exceed available emergency department (ED) resources. The Canadian Triage and Acuity Scale (CTAS) is the standard used in all Canadian and many international EDs to aid in safely determining the priority by which patients should be assessed. The scale delineates 5 levels of acuity: level 1 (resuscitation), level 2 (emergent), level 3 (urgent), level 4 (less urgent) and level 5 (non-urgent).

Many provincial governments use CTAS as an administrative metric to estimate patient care requirements, compare ED performance, and estimate ED physician staffing needs. Despite its clinical and administrative importance, the process by which CTAS scores are derived is highly variable. eCTAS is a real-time electronic decision-support tool designed to standardize the application CTAS guidelines.

This dissertation includes three scientific papers that describe the evaluation of the provincial implementation of eCTAS in hospital EDs across Ontario. This thesis first describes the results from a prospective, observational study of nearly 1,500 triage encounters from sevens EDs that found that a standardized, electronic approach to performing triage assessments improves both interrater agreement and data accuracy compared to each hospital's previous triage process, without substantially increasing triage time.

We then present our findings from a study exploring the consistency of CTAS score distributions across 35 hospital EDs pre and post-eCTAS implementation for 16 high-volume presenting complaints, and describe the association between use of eCTAS clinical modifiers and triage consistency. We found that compared to the previous triage process, eCTAS increased triage consistency across many, but not all, high-volume presenting complaints. Modifier use was associated with increased triage consistency, particularly for non-specific complaints such as fever and general weakness.

The third paper includes data from 354,176 triage encounters from 31 EDs and describes a change in the distribution of triage scores (from higher to lower acuity) that is likely due to eCTAS implementation. It also explores the possible impact of eCTAS implementation on the ED metrics of hospital admission, left without being seen, and time from triage to physician initial assessment, finding low quality evidence of minimal if any impact of eCTAS on these outcomes. Finally, this thesis concludes with suggestions for future research in this area.

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LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
ANOVA	Analysis of Variance
ATS	Australasian Triage Scale
CCO	Cancer Care Ontario
CI	Confidence Interval
CIHI	Canadian Institute of Health Information
CTAS	Canadian Triage and Acuity Scale
CTAS 1	Resuscitation
CTAS 2	Emergent
CTAS 3	Urgent
CTAS 4	Less urgent
CTAS 5	Non-urgent
CVA	Cerebrovascular Accident
eCTAS	electronic Canadian Triage and Acuity Scale
ED	Emergency Department
ESI	Emergency Severity Index
GEE	Generalized Estimating Equation

GRADE	Grading of Recommendations Assessment, Development and Evaluation
High Volume	50,000 to 84,999 annual ED visits
HV	High Volume
IQR	Interquartile Range
K	Kappa Statistic
Low Volume	<30,000 annual ED visits
LV	Low Volume
LWBS	Rate of Left Without Being Seen
Med Volume	30,000 to 49,999 annual ED visits
Min	Minutes
MoH	Ministry of Health
MTS	Manchester Triage Scale
MV	Medium Volume
n/a	Not Applicable
NACRS	National Ambulatory Care Reporting System
OHIP	Ontario Health Insurance Plan Number
OR	Odds Ratio
PIA	Time from Triage to Physician Initial Assessment

post-eCTAS	Prior to the Implementation of eCTAS
pre-eCTAS	After the Implementation of eCTAS
QIC	Quasi-likelihood under Independence Model Criterion
SD	Standard Deviation
Sec	Seconds
T	Teaching
Very-High Volume	>85,000 annual ED visits
VHV	Very High Volume
Δ	Difference

DECLARATION OF ACADEMIC ACHIEVEMENT

I was the main contributor and first author for all studies. Detailed lists of author contributions are provided at the end of each chapter.

This dissertation is a "sandwich" thesis, composed of three scientific papers, the first of which is described in Chapter 2 and has been published in the *Annals of Emergency Medicine* (impact factor 5.35). The second manuscript detailed in Chapter 3 has been accepted for publication with the *Journal of the American College of Emergency Physicians Open*, and the third paper described in Chapter 4 is currently under review with the *Canadian Medical Association Journal Open*.

Chapter 1 and Chapter 5 are unpublished and I was the sole author.

CHAPTER 1: INTRODUCTION OF THE THESIS

Triage is a fundamental process for the safe and efficient management of patients where health care demands exceed available emergency department (ED) resources. The ED evaluation begins at arrival, when patients undergo triage by ED personnel and are assigned a priority score based on perceived clinical urgency. The Canadian Triage and Acuity Scale (CTAS) is the standard used in all Canadian and many international EDs to aid in safely determining the priority by which patients should be assessed.<1-7> The intent is to identify patients with critical and time-sensitive conditions who should be seen expeditiously to initiate care that results in optimal morbidity and mortality outcomes.

The scale delineates 5 levels of acuity: level 1 (resuscitation), level 2 (emergent), level 3 (urgent), level 4 (less urgent) and level 5 (non-urgent).<8-11> CTAS is similar to other standardized triage algorithms including the Australasian Triage Scale <12> and the Manchester Triage Scale <13>, which categorize patients based on the time they may safely wait, but differs from other triage algorithms such as the Emergency Severity Index <14>, which also incorporates the anticipated number of resources that may be required. CTAS and the MTS also differ from the other triage algorithms by including standardized presenting complaint lists.<15-16>

Many provincial governments also use CTAS as an administrative metric to estimate patient care requirements, compare ED performance, and estimate ED physician staffing needs.<17-20> However, despite its clinical and administrative importance, the process by which CTAS scores are derived is highly variable.<4,5,21-24> According to a 2010 report from the Ontario Auditor General, 38% of Ontario ED patients were being “under-triaged”, and there was no process in

place to validate submitted triage scores, resulting in a lack of transparency and accountability for ED funding.<25> Although the original CTAS training document is comprehensive, traditional application of the CTAS guidelines has been based on memory and experience. In 2015, the Ontario government agreed to fund the development and implementation of a standardized, electronic solution to reduce triage variability across the province.<26>

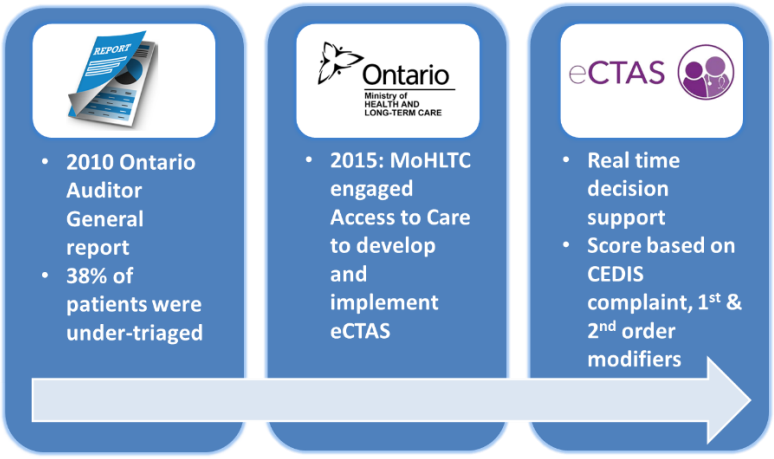

Figure 1. Flow of eCTAS development.

eCTAS is a real-time electronic decision-support tool, designed to standardize the application of national triage guidelines.<26-27> The eCTAS system was based on the concept of the eTRIAGE algorithm reported by Dong *et al*., which uses a web-based platform to display a list of presenting complaints with corresponding criteria and definitions to assist the user in assigning a triage score.<28-30> In order to ensure an intuitive, user-friendly design, eCTAS was further informed by a comprehensive needs assessment and environmental scan, including 24 hospital site visits of teaching, community, and rural EDs, and consultation with over 100 clinical and technical experts from across the province.

The application requires the user to select a presenting complaint from a standardized list of 169 complaints (Table 1) and then displays a CTAS-based template with complaint-specific modifiers (e.g., vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) to help ensure high risk time-sensitive conditions are not missed (Table 2). This assists the user in assigning the appropriate CTAS score in real time.

Table 1. The Canadian Emergency Department Information System (CEDIS) presenting complaint list (V2.0).

Canadian Emergency Department Information System (CEDIS) Presenting Complaint List (V2.0) Effective Date: April 2012					
Cardiovascular (001–050)	**#**	**Environmental (201–250)**	**#**	**Genitourinary (301–350) cont'd**	**#**
Cardiac arrest (non-traumatic)	001	Frostbite/cold injury	201	Polyuria	309
Cardiac arrest (traumatic)	002	Noxious inhalation	202	Genital trauma	310
Chest pain—cardiac features	003	Electrical injury	203	**Mental Health (351–400)**	**#**
Chest pain—non-cardiac features	004	Chemical exposure	204	Depression/suicidal/deliberate self-harm	351
Palpitations/irregular heart beat	005	Hypothermia	205	Anxiety/situational crisis	352
Hypertension	006	Near drowning	206	Hallucinations/delusions	353
General weakness	007	**Gastrointestinal (251–300)**	**#**	Insomnia	354
Syncope/pre-syncope	008	Abdominal pain	251	Violent/homicidal behaviour	355
Edema, generalized	009	Anorexia	252	Social problem	356
Bilateral leg swelling/edema	010	Constipation	253	Bizarre behaviour	358
Cool pulseless limb	011	Diarrhea	254	Concern for patient's welfare	359
Unilateral reddened hot limb	012	Foreign body in rectum	255	Pediatric disruptive behaviour	360
ENT—Ears (051–100)	**#**	Groin pain/mass	256	**Neurologic (401–450)**	**#**
Earache	051	Nausea and/or vomiting	257	Altered level of consciousness	401
Foreign body, ear	052	Rectal/perineal pain	258	Confusion	402
Loss of hearing	053	Vomiting blood	259	Vertigo	403
Tinnitus	054	Blood in stool/melena	260	Headache	404
Discharge, ear	055	Jaundice	261	Seizure	405
Ear injury	056	Hiccoughs	262	Gait disturbance/ataxia	406
ENT—Mouth, Throat, Neck (101–150)	**#**	Abdominal mass/distention	263	Head injury	407
Dental/gum problem	101	Anal/rectal trauma	264	Tremor	408
Facial trauma	102	Oral/esophageal foreign body	265	Extremity weakness/symptoms of CVA	409
Sore throat	103	Feeding difficulties in newborn	266	Sensory loss/paresthesia	410
Neck swelling/pain	104	Neonatal jaundice	267	Floppy child	411
Neck trauma	105	**Genitourinary (301–350)**	**#**	**OB/GYN (451–500)**	**#**
Difficulty swallowing/dysphagia	106	Flank pain	301	Menstrual problems	451
Facial pain (non-traumatic/non-dental)	107	Hematuria	302	Foreign body, vagina	452
ENT—Nose (151–200)	**#**	Genital discharge/lesion	303	Vaginal discharge	453
Epistaxis	151	Penile swelling	304	Sexual assault	454
Nasal congestion/hay fever	152	Scrotal pain and/or swelling	305	Vaginal bleed	455
Foreign body, nose	153	Urinary retention	306	Labial swelling	456
URTI complaints	154	UTI complaints	307	Pregnancy issues, <20 weeks	457
Nasal trauma	155	Oliguria	308	Pregnancy issues, >20 weeks	458

Canadian Emergency Department Information System (CEDIS) Presenting Complaint List (V2.0) (cont'd)					
Effective Date: April 2012					
OB/GYN (451–500) cont'd	**#**	**Skin (701–750)**	**#**	**General and Minor (851–900) cont'd**	**#**
Vaginal pain/dyspareunia	460	Bite	701	Direct referral for consultation	855
Ophthalmology (501–550)	**#**	Sting	702	Dressing change	856
Chemical exposure, eye	502	Abrasion	703	Removal staples/sutures	857
Foreign body, eye	503	Laceration/puncture	704	Cast check	858
Visual disturbance	504	Burn	705	Imaging tests	859
Eye pain	505	Blood and body fluid exposure	706	Medical device problem	860
Red eye, discharge	506	Pruritus	707	Prescription/medication request	861
Photophobia	507	Rash	708	Ring removal	862
Diplopia	508	Localized swelling/redness	709	Abnormal lab values	863
Periorbital swelling	509	Wound check	710	Pallor/anemia	864
Eye trauma	510	Other skin conditions	711	Post-operative complications	865
Re-check eye	511	Lumps, bumps, calluses	712	Minor complaints NOS	866
Orthopedic (551–600)	**#**	Redness/tenderness, breast	713	Inconsolable crying	867
Back pain	551	Rule out infestation	714	Congenital problem in children	868
Traumatic back/spine injury	552	Cyanosis	715	Newly Born	869
Amputation	553	Spontaneous bruising	716	**Unknown**	**999**
Upper extremity pain	554	Foreign body, skin	717		
Lower extremity pain	555	**Substance Misuse (751–800)**	**#**		
Upper extremity injury	556	Substance misuse/intoxication	751		
Lower extremity injury	557	Overdose ingestion	752		
Joint(s) swelling	558	Substance withdrawal	753		
Pediatric gait disorder/painful walk	559	**Trauma (801–850)**	**#**		
Respiratory (651–700)	**#**	Major trauma—penetrating	801		
Shortness of breath	651	Major trauma—blunt	802		
Respiratory arrest	652	Isolated chest trauma—penetrating	803		
Cough/congestion	653	Isolated chest trauma—blunt	804		
Hyperventilation	654	Isolated abdominal trauma—penetrating	805		
Hemoptysis	655	Isolated abdominal trauma—blunt	806		
Respiratory foreign body	656	**General and Minor (851–900)**	**#**		
Allergic reaction	657	Exposure to communicable disease	851		
Stridor	658	Fever	852		
Wheezing—no other complaints	659	Hyperglycemia	853		
Apneic spells in infants	660	Hypoglycemia	854		

Sources
Canadian Association of Emergency Physicians (CAEP); Canadian Institute for Health Information (CIHI).

Hospitals have multiple options for how they implement the solution, allowing them to choose the option that best suits their needs. They can use the provincial, clinically designed web application, or they can incorporate provincial CTAS decision support into their own hospital systems, designing and developing their own triage screens.

Prior to the implementation of eCTAS, all triage nurses completed a mandatory 2-hour training session consisting of didactic teaching and application practice using an online, interactive, simulated training environment with 10 standardized triage scenarios and real-time instruction on how to incorporate vital signs and relevant modifiers. For ongoing eCTAS training, all triage nurses have access to a training environment as soon as they receive their access code and can continue to access this environment for future training and updates. When eCTAS updates are implemented, there is an education session in the form of a train-the-trainer that includes a full teaching module to allow hospital trainers to share the updates. There is also a help guide built into the eCTAS tool where a nurse can search any aspect of the tool and will get a visual guide to the section in question with a full training step-by-step guide; there are also videos in this section. As of February 2020, eCTAS has been provincially mandated and implemented in 115 (>90%) EDs across Ontario.

As a member of the eCTAS steering committee, I had the opportunity to lead the research evaluation of the eCTAS program. This dissertation combines three scientific papers that describe research findings from the evaluation of the provincial implementation of eCTAS in hospital EDs across Ontario.

CHAPTER 2 describes our results from a prospective, observational study of nearly 1,500 triage encounters that occurred in seven hospital EDs across Ontario. This was the first study to report interrater reliability, agreement and triage time pre and post-eCTAS implementation.

CHAPTER 3 presents our findings from a study exploring the consistency of CTAS score distributions across 35 hospital EDs pre and post-eCTAS implementation for 16 high-volume presenting complaints, and describes the association between use of eCTAS modifiers and triage consistency. To determine consistency, the overall CTAS distribution was first calculated for each presenting complaint, pre and post-eCTAS. Then the absolute difference in CTAS distribution for each presenting complaint was calculated for each hospital, resulting in a change score. Consistency ratios with a value >1.0 indicate an increase in triage consistency post-eCTAS.

CHAPTER 4 describes the possible impact of eCTAS implementation on the ED metrics of hospital admission, rate of left without being seen, and time from triage to physician initial assessment, and describes a change in the distribution of triage scores post-eCTAS that is likely due to eCTAS implementation. Quality of evidence refers to our confidence that changes were causally related to eCTAS implementation.

CHAPTER 5 summarizes the most important findings from the three scientific papers and suggests opportunities for future research in this area.

Table 2. List of clinical modifiers available in eCTAS.

	Modifiers
1	< 3 mos, T < 36C OR > 38C
2	> 18 mos, T > 38.5C and Appearing Unwell (Toxic)
3	> 18 mos, T > 38.5C and Appearing Well (Non-toxic)
4	3-18 mos, T < 36C OR > 38.5C and Appearing Unwell (Toxic)
5	3-18 mos, T < 36C OR > 38.5C and Appearing Well (Non-toxic)
6	Abuse (any), High Stress
7	Active Bleeding
8	Active Labor (Contractions = < 5 min)
9	Active Labor (Contractions >5 min)
10	Active or Significant Hematemesis
11	Active Significant Hematemesis
12	Active Suicidal Intent
13	Active Vaginal Bleeding
14	Active Vaginal Bleeding with Clots
15	Actively Seizing
16	Actively Seizing (Substance Withdrawal)
17	Actively Seizing or Postictal
18	Acute Central Mild Pain (< 4)
19	Acute Central Moderate Pain (4-7)
20	Acute Central Severe Pain (8-10)
21	Acute Difficulties with Others / Environment
22	Acute Epistaxis, No Active Bleeding
23	Acute Inability to Ambulate
24	Acute Insomnia
25	Acute Mild Pain (< 4)
26	Acute Moderate Pain (4-7)

27 Acute Onset Diplopia
28 Acute Onset, Ongoing
29 Acute or Abrupt Change in Vision (Eye Pain)
30 Acute or Abrupt Change in Vision (Eye Trauma)
31 Acute or Abrupt Change In Vision (Foreign Body, Eye)
32 Acute or Abrupt Change In Vision (Re-check eye)
33 Acute or Abrupt Change in Vision (Visual Disturbance)
34 Acute Peripheral Mild Pain (< 4)
35 Acute Peripheral Moderate Pain (4-7)
36 Acute Peripheral Severe Pain (8-10)
37 Acute Psychosis
38 Acute Severe Pain (8-10)
39 Acute, No Headache
40 Acute, with Headache and/or Altered LOC
41 Airway Compromise
42 Altered Level of Consciousness (GCS 10-13)
43 Amputation
44 Amputation (Ear Injury)
45 Anal / Rectal Trauma
46 Anorexia, Looks Well
47 Apneic Spell on Presentation
48 Appears Well, No Fever
49 Asthmatic, PEFR < 40% (Severe)
50 Asthmatic, PEFR > 60% (Mild)
51 Asthmatic, PEFR 40%-60% (Moderate)
52 Attempted Suicide or Clear Plan
53 Attempted Suicide or Clear Plan (Overdose Ingestion)
54 Audible Stridor

55 Blanching of Skin
56 Bleeding Controlled With Pressure
57 Bleeding Disorder (Life or Limb Threatening Bleed)
58 Bleeding Disorder (Moderate or Minor Bleeds)
59 Bleeding Resolved / Controlled
60 Bleeding/Spotting + Cramping >10 Days Post Partum
61 Blunt MOI with Visual Loss
62 Bright Red Bleeding/Spotting <5 Days Postpartum
63 BS < 4 mmol/l and asymptomatic child > 1yr
64 BS < 4 mmol/l and symptomatic child > 1yr
65 BS < 4 mmol/L and/or Symptomatic
66 BS < 4 mmol/L, Infant < 1 Year
67 BS < 4 mmol/L, Not Symptomatic
68 BS < 4 mmol/L, Symptomatic
69 BS > 18 mmol/L, Not Symptomatic
70 BS > 18 mmol/L, Symptomatic
71 Burn < 5% BSA Full or < 10% Partial
72 Burn > 25% BSA
73 Burn 5%-25% BSA
74 Button Battery, No Symptoms (Foreign Body, Nose)
75 Button Battery, No Symptoms (Oral / Esophageal Foreign Body)
76 Button Battery, No Symptoms (Respiratory Foreign Body)
77 Cardiac Arrest (Non-traumatic)
78 Cardiac Arrest (Traumatic)
79 Caregivers Identifying Need for Care
80 Cast Check or Cast Change
81 Chemical Exposure
82 Chemical Exposure, Eye

83 Chest Pain, Cardiac Features

84 Chest Pain, Non Cardiac

85 Chills, Wound Redness or Purulent Drainage

86 Chronic / Gradual Change in Vision

87 Chronic Abdominal Mass / Distention

88 Chronic Central Mild Pain (< 4)

89 Chronic Central Moderate Pain (4-7)

90 Chronic Central Severe Pain (8-10)

91 Chronic Confusion, No Change from Usual State

92 Chronic Cough / Congestion, Normal VS

93 Chronic Diarrhea, Normal VS

94 Chronic Diplopia

95 Chronic Insomnia

96 Chronic Mild Pain (<4)

97 Chronic Moderate Pain (4-7)

98 Chronic or Recurring Headache

99 Chronic Peripheral Mild/Moderate Pain (< 8)

100 Chronic Peripheral Severe Pain (8-10)

101 Chronic Sensory Loss / Paresthesias

102 Chronic Severe Pain (8-10)

103 Chronic Tremor

104 Chronic Vertigo

105 Chronic Vomiting and/or Nausea

106 Chronic Weakness

107 Chronic, non Urgent Condition (Bizarre Behaviour)

108 Chronic, non Urgent Condition (Social Problem)

109 Chronic, Unchanged Behaviour

110 Coffee Ground Emesis/Melena (Vomiting and/or Nausea)

111 Coffee Ground Emesis/Melena (Vomiting Blood)

112 Cold Pulseless Limb

113 Conditions/Protocol Letters/Rapid Deterioration/Immediate Therapy

114 Conflict or Unstable Situation

115 Conflict or Unstable Situation

116 Constipation

117 Controlled Bizarre Behaviour

118 Cool Pulseless Limb

119 Core Temperature < 32C (Drowning)

120 Core Temperature < 32C (Hypothermia)

121 Core Temperature > 41C

122 Core Temperature 32-35C (Drowning)

123 Core Temperature 32-35C (Hypothermia)

124 Core Temperature 39C - 41C

125 Cramping

126 Critical Value, Normal VS

127 Cyanosis

128 Decreased Fetal Movement

129 Decreased Oral Intake

130 Dental / Gum Problem

131 Dental Avulsion (Recent with Intact Tooth Present)

132 Depressed, No Suicidal Ideation

133 Difficulty Swallowing

134 Difficulty Swallowing/Dysphagia

135 Difficulty Swallowing/No Resp Distress

136 Direct Referral for Consultation

137 Dressing Change

138 Drooling or Stridor (Difficulty Swallowing / Dysphagia)

139 Drooling or Stridor (Oral / Esophageal Foreign Body)

140 Drooling or Stridor (Respiratory Foreign Body)

141 Drooling or Stridor (Sore Throat)

142 Edema / Bilateral

143 Edema, Generalized, Normal VS

144 Exposure to Communicable Disease

145 Extensive Inflammation

146 Facial Cellulitis, Particularly Periorbital Area (Localized Swelling / Redness)

147 Facial Cellulitis, Particularly Periorbital Area (Rash)

148 Facial Pain (Non-Traumatic / Non-Dental)

149 Facial Trauma

150 Family Distress

151 Fever (Appears Well), 1 SIRS Criterion (Fever)

152 Fever (Looks Unwell), < 3 SIRS Criteria

153 Fever, Immunocompromised

154 Foreign Body in Ear

155 Foreign Body in Nose

156 Foreign Body in Rectum

157 Foreign Body Vagina

158 Foreign Body, Skin

159 Frailty Modifier

160 Frostbite / Cold Injury

161 Gait or painful walking with Fever

162 Genital Discharge / Lesion

163 Genital Trauma, No Pain

164 Groin Pain / Mass

165 Harmless Behaviour

166 Hay Fever Causing Nasal Congestion

167 Headache +/- Edema +/- Epigastric Pain +/- Visual Disturbance +/- CVA Symptoms

168 Headache +/- Edema +/- Epigastric Pain +/- Visual Disturbance +/- CVA Symptoms (Pregnancy Issues > 20 wks)

169 Hearing Loss, Gradual Onset

170 Hearing Loss, Sudden Onset

171 Heat Cramps Resolving, Well Hydrated

172 Heavy Vaginal Bleeding

173 Heavy Vaginal Bleeding +/- Pregnancy

174 Hematuria

175 Hemodynamic Compromise

176 Hemoptysis, Appears Well

177 Hiccoughs Chronic, No Distress

178 High Risk Exposure

179 High Risk Mechanism of Injury

180 High Risk Substance / Unknown Substance (Overdose Ingestion)

181 High Risk Substance / Unknown Substance (Substance Misuse / Intoxication)

182 High Risk Substance Abuse (Postpartum Issues)

183 High Risk Substance Abuse (Pregnancy Issues > 20 Weeks)

184 History / Signs of Abuse or Maltreatment

185 History Of Bleeding Prior To Presentation

186 History of Loss of Consciousness

187 History of Spell Consistent with Apnea

188 History of Spell Consistent with Apnea (Stridor)

189 History/Documentation of Lethal Dysrhythmia

190 Hoarseness or Difficulty Speaking (Neck Trauma)

191 Hoarseness or Difficulty Speaking (Oral / Esophageal Foreign Body)

192 Hoarseness or Difficulty Speaking (Respiratory Foreign Body)

193 Hx of Palpitations, Resolved

194 Hypertension SBP >140 And DBP >90 (Postpartum Issues)

195 Hypertension SBP >140 And DBP >90 (Pregnancy Issues > 20 weeks)

196 Hypertension SBP >160 And DBP >100 (Postpartum Issues)

197 Hypertension SBP >160 And DBP >100 (Pregnancy Issues > 20 weeks)

198 Hyperventilation Resolved, Appears Well

199 Imaging Test / Blood Test

200 Imminent Harm to Self or Others

201 Inconsolable Infant - VS outside of Normal Limits

202 Inconsolable Infant, Abnormal VS

203 Infant < 7 days of Age

204 Infant <= 7 Days of Age

205 Infant > 7 Days of Age

206 Irritable but Consolable

207 Isolated Abdominal Blunt Trauma

208 Isolated Abdominal Trauma - Penetrating

209 Isolated Chest Trauma - Blunt (Appears Well)

210 Isolated Chest Trauma - Penetrating

211 Jaundice, Looks Well

212 Joint Swelling

213 Known Low Risk Substance

214 Labial Swelling

215 Laceration / Abrasion, No Sutures required

216 Laceration Requiring Sutures

217 Large Amt, Melena / Rectal Bleeding

218 Limited / Less Than Expected Muscle Tone

219 Localized Cellulitis (Localized Swelling / Redness)

220 Localized Cellulitis (Rash)

221 Localized Inflammation

222 Localized Rash

223 Localized Rash (Localized Swelling/Redness)

224 Looks Septic (3 SIRS Criteria)

225 Looks Well

226 Low Risk Exposure

227 Lumps, Bumps, Calluses

228 Major Blunt Trauma In Pregnancy >20 Weeks

229 Major Blunt Trauma in Pregnancy >20 Weeks

230 Major Burn > 25% BSA

231 Major Burn Hand, Feet, Groin or Face

232 Major Trauma - Blunt

233 Major Trauma - Penetrating

234 Marked Stridor

235 Medical Device Problem; 'Asymptomatic' or 'No Distress'

236 Menstrual Problems

237 Mild Agitation, Stable

238 Mild Anxiety / Agitation (Anxiety / Situational Crisis)

239 Mild Anxiety / Agitation (Substance Withdrawal)

240 Mild Anxiety / Agitation, Chronic Hallucinations

241 Mild Dehydration (Diarrhea)

242 Mild Dehydration (General Weakness)

243 Mild Dehydration (Heat Related Issue)

244 Mild Dehydration (Medical Device Problem)

245 Mild Dehydration (Vomiting and/or Nausea)

246 Mild Respiratory Distress

247 Mild Symptoms

248 Mild To Moderate Vaginal Bleeding

249 Mild/Moderate Headache +/- Non Dependant Edema

250 Minor Abrasion

251 Minor Bite(s)

252 Minor Blunt Trauma in Pregnancy >20 Weeks

253 Minor Cold Injury, No Discolouration

254 Minor Complaints, Unspecified

255 Minor Sore Throat +/- Laryngitis

256 Minor Trauma - No Direct Abdominal Trauma

257 Moderate Amt, Melena / Rectal Bleeding

258 Moderate Anxiety / Agitation

259 Moderate Anxiety / Agitation (Anxiety / Situational Crisis)

260 Moderate Anxiety / Agitation (Substance Withdrawal)

261 Moderate Dehydration (Diarrhea)

262 Moderate Dehydration (Feeding Difficulties in Newborn)

263 Moderate Dehydration (General Weakness)

264 Moderate Dehydration (Heat Related Issue)

265 Moderate Dehydration (Medical Device Problem)

266 Moderate Dehydration (Neonatal Jaundice)

267 Moderate Dehydration (Vomiting and / or Nausea)

268 Moderate Respiratory Distress

269 More Than 7 Days, No Distress

270 Nasal Congestion with Known Hay Fever

271 Near Drowning, Appears Well

272 Neck Stiffness/Meningismus +/- Fever

273 Neuro-deficit +/- Bowel Bladder Problems (Back Pain)

274 Neuro-deficit +/- Bowel Bladder Problems (Traumatic Back / Spine Injury)

275 Neurovascular Compromise (Bite)

276 Neurovascular Compromise (Laceration / Puncture)

277 Neurovascular Compromise (Lower Extremity Injury)

278 Neurovascular Compromise (Lower Extremity Pain)

279 Neurovascular Compromise (Ring Removal)

280 Neurovascular Compromise (Upper Extremity Injury)

281 Neurovascular Compromise (Upper Extremity Pain)

282 Neurovascular Compromise of Extremity (Multisystem Trauma - Blunt)

283 Neurovascular Compromise of Extremity (Multisystem Trauma - Penetrating)

284 New Dysrhythmia, Irreg Pulse/HR Change

285 New Focal Neurological Findings

286 New Onset Sensory Loss / Paresthesias

287 Newly Born

288 No Distress

289 No Fetal Movement

290 No Frostbite, Normal VS

291 No History of Loss of Consciousness

292 No Muscle Tone, Unable to Support Head

293 No Obvious Cutaneous Injury

294 No Sutures Required

295 No Swallowing / Respiratory Difficulty

296 Non-critical Abnormal Lab Value

297 Not Positional, +/- Neuro Findings

298 Nurse Unable to Visualize Eye

299 Obvious Cutaneous Injury

300 Obvious Deformity (Upper Extremity Injury)

301 Obvious Deformity (Lower Extremity Injury)

302 Obvious Edema / Swelling of Lips, Tongue or Oropharynx

303 Oliguria

304 Ongoing Heat Cramps

305 Open Fracture (Lower Extremity Injury)

306 Open Fracture (Upper Extremity Injury)

307 Other Significant Chest Pain (Ripping, Tearing)

308 Other Skin Conditions

309 Outside the Therapeutic Window or Resolved

310 Overdose Ingestion

311 Painless Mild Burn

312 Pallor / Anemia

313 Paranoia

314 Paresthesias, Neurological Signs

315 Partial/Full Thickness Burn to Hands, Feet, Face, or Perineum

316 Pelvic Pain with Abnormal Vaginal Discharge

317 Pelvic Pressure With Abdominal Cramping, Back Pain

318 Penetrating Abdominal Trauma In Pregnancy >20 Weeks

319 Penetrating Abdominal Trauma in Pregnancy >20 Weeks

320 Penetrating Foreign Body

321 Penetrating Head, Chest, Abdomen

322 Penetrating Injury/Chemical or Thermal Burn

323 Periodic / Recurrent, No Active Bleeding

324 Periorbital Swelling

325 Persistent Headache Post Epidural Anesthesia with Delivery

326 Persistent Problematic Behaviour

327 Persistent Vomiting (Abdominal Mass / Distention)

328 Persistent Vomiting (Oral / Esophageal Foreign Body)

329 Petechial Rash

330 Photophobia

331 Pink, Mucous Discharge

332 Polyuria

333 Positional, No Other Neuro Symptoms

334 Possible Foreign Body
335 Possible Vaginal Fluid Leak
336 Postictal (Seizure)
337 Potential for Dehydration (Diarrhea)
338 Potential for Dehydration (General Weakness)
339 Potential for Dehydration (Medical Device Problem)
340 Potential for Dehydration (Vomiting and / or Nausea)
341 Prescription / Medication Request
342 Presenting Fetal Parts or Prolapsed Cord
343 Previous Severe Reaction (Bite)
344 Previous Severe Reaction (Sting)
345 Previous Severe Reaction (Allergic Reaction)
346 Priapism
347 Prolonged Spinal Immobilization
348 Prolonged Spinal Immobilization (Head Injury)
349 Prolonged Spinal Immobilization (Multisystem Trauma - Blunt)
350 Pruritus
351 Pulse Rate / Pressure Abnormal (Hemodynamically Stable)
352 Purpuric / Petechial Rash, Appears Unwell (Localized Swelling / Redness)
353 Purpuric / Petechial Rash, Appears unwell (Rash)
354 Recent Seizures, Postictal, Agitated (Substance Withdrawal)
355 Recent Spell Consistent with Apnea
356 Recent Spell Consistent with Apnea (Stridor)
357 Re-check Eye
358 Rectal Bleeding Small Amount
359 Red Eye / Discharge, Acute
360 Red Eye / Discharge, Chronic
361 Redness / Tenderness Breast

362 Redness, Tenderness in Breast
363 Refusing Oral Feeds
364 Remote Exposure, No Symptoms
365 Removal of Staples / Sutures
366 Resolved, Normal Level of Alertness
367 Respiratory Arrest
368 Retracted Foreskin, Unable To Reduce
369 Ring Removal
370 Risk of Flight or Ongoing Abuse
371 Routine Check, Normal VS
372 Rule out Infestation
373 SBP > 220 or DBP > 130, No Symptoms
374 SBP > 220 or DBP > 130, With Symptoms
375 SBP 200-220 and DBP 110-130, No Symptoms
376 SBP 200-220 and DBP 110-130, With Symptoms
377 Scrotal Pain and/or Swelling
378 Severe Anxiety / Agitation (Anxiety / Situational Crisis)
379 Severe Anxiety / Agitation (Substance Withdrawal)
380 Severe Anxiety or Agitation
381 Severe Cold Injury, Blanching or Cyanosis
382 Severe Dehydration (Diarrhea)
383 Severe Dehydration (Feeding Difficulties in Newborn)
384 Severe Dehydration (General Weakness)
385 Severe Dehydration (Heat Related Issue)
386 Severe Dehydration (Medical Device Problem)
387 Severe Dehydration (Neonatal Jaundice)
388 Severe Dehydration (Vomiting and / or Nausea)
389 Severe Respiratory Distress

390 Sexual Assault (or Suspected), Stable

391 Shock

392 Shortness of Breath, No Distress

393 Significant Weight Loss

394 Signs of Deep Space Infection or Injury

395 Small Amount, Normal Vital Signs

396 Smoke/Other Inhalation, No Distress

397 Specific Plan(s) to do harm

398 Spontaneous Bruising

399 Spotting

400 Stable, Potential for Problems

401 Stable, Progressing As Expected

402 Sting

403 Sudden, Severe, Worst Ever Headache

404 Suicidal Ideation No Plan (Overdose Ingestion)

405 Suicidal Ideation No Plan (Depression / Suicidal / Deliberate Self Harm)

406 Suspected Aspirin Ingestion

407 Suspected Physical or Sexual Assault

408 Sutures Required

409 Symptomatic Eye 'Splash'

410 Syncope Occurring During Exercise

411 Syncope with No Prodromal Symptoms

412 Syncope with Prodromal Symptoms

413 Syncope with Sudden Position Change

414 Syncope with Symptoms Resolved, Normal VS

415 Tight Cast with Neuro-vascular Compromise (Lower Extremity Injury)

416 Tight Cast with Neuro-vascular Compromise (Cast Check)

417 Tight Cast with Neuro-vascular Compromise (Lower Extremity Pain)

418 Tight Cast with Neuro-vascular Compromise (Upper Extremity Injury)
419 Tight Cast with Neuro-vascular Compromise (Upper Extremity Pain)
420 Tight Cast with No Neuro-vascular Compromise (Cast Check)
421 Tight Cast with No Neuro-vascular Compromise (Lower Extremity Injury)
422 Tight Cast with No Neuro-vascular Compromise (Lower Extremity Pain)
423 Tight Cast with No Neuro-vascular Compromise (Upper Extremity Injury)
424 Tight Cast with No Neuro-vascular Compromise (Upper Extremity Pain)
425 Tinnitus
426 Traumatic Amputation of a Digit
427 Traumatic Amputation of an Extremity
428 Unable to Cope
429 Unable To Empty Bladder/Dysuria <72 Hrs Postpartum
430 Uncertain Flight or Safety Risk (Anxiety / Situational Crisis)
431 Uncertain Flight or Safety Risk (Bizarre Behaviour)
432 Uncertain Flight or Safety Risk (Depression / Suicidal / Deliberate Self Harm)
433 Uncertain Flight or Safety Risk (Hallucinations / Delusions)
434 Uncertain Flight or Safety Risk (Overdose Ingestion)
435 Uncertain Flight or Safety Risk (Paediatric Disruptive Behaviour)
436 Uncertain Flight or Safety Risk (Substance Misuse / Intoxication)
437 Uncertain Flight or Safety Risk (Substance Withdrawal)
438 Uncertain Flight or Safety Risk (Violent / Homicidal Behaviour)
439 Unconscious (GCS 3-9)
440 Uncontrolled Bizarre Behaviour
441 Uncontrolled Bloody Diarrhea
442 Uncontrolled Epistaxis
443 Uncontrolled Epistaxis
444 Unplanned / Unattended Birth
445 Upper Extremity Chronic Mild Pain

446	Urinary Retention
447	UTI Complaints / Symptoms
448	Vaginal Bleeding - Minor / Spotting (Vaginal Bleed)
449	Vaginal Bleeding - Normal VS
450	Vaginal Discharge
451	Vaginal Fluid Loss
452	Violent Ideation, No Plan
453	Visual Acuity Disturbance +/- Eye Pain
454	Vital Signs Outside the Limits of Normal
455	Vomiting / Diarrhea in a Child with Metabolic Disease, Type 1 Diabetes or Adrenal Insufficiency
456	Wakeup Stroke or Within the Therapeutic Window
457	Wakeup Stroke or Within the Therapeutic Window
458	Walking with Difficulty
459	Wheezing - No Other Complaints
460	With Chest Pain Cardiac Features
461	Within Last 24 Hours or Distressed
462	Within Last 7 Days
463	Wound Check
464	Wound Redness/Swelling +/- Serosanguinous Drainage

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CHAPTER 2: INTERRATER RELIABILITY, ACCURACY AND TRIAGE TIME PRE AND POST-IMPLEMENTATION OF A REAL TIME ELECTRONIC TRIAGE DECISION-SUPPORT TOOL.

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ABSTRACT

Objective: eCTAS is a real time electronic triage decision-support tool designed to improve patient safety and quality of care by standardizing the application of the Canadian Triage and Acuity Scale (CTAS). The objective of this study was to determine interrater agreement of triage scores pre- and post-implementation of eCTAS.

Methods: This was a prospective, observational study conducted in seven EDs, selected to represent a mix of triage documentation practices, hospital types and patient volumes. A provincial CTAS auditor observed triage nurses in the ED pre- and post-implementation of eCTAS and assigned an independent CTAS score in real time. Research assistants independently recorded triage time. Interrater agreement was estimated using kappa statistics with 95% confidence intervals (CIs).

Results: 1491 (752 pre-eCTAS, 739 post-implementation) individual triage assessments were audited over 42 (21 pre-eCTAS, 21 post-implementation) seven-hour triage shifts. Exact modal agreement was achieved for 567 (75.4%) patients pre-eCTAS, compared to 685 (92.7%) patients triaged with eCTAS. Using the auditor's CTAS score as the reference, eCTAS significantly reduced the number of patients over-triaged (12.0% vs. 5.1%; Δ 6.9, 95% CI: 4.0, 9.7) and under-triaged (12.6% vs. 2.2%; Δ 10.4, 95% CI: 7.9, 13.2). Interrater agreement was higher with eCTAS (unweighted kappa 0.89 vs 0.63; quadratic-weighted kappa 0.93 vs. 0.79). Median triage time was 312 seconds (n=3808 patients) pre-eCTAS and 347 seconds (n=3489 patients) with eCTAS (Δ 35 seconds, 95% CI: 29, 40 seconds).

Conclusions: A standardized, electronic approach to performing triage assessments improves both interrater agreement and data accuracy without substantially increasing triage time.

Introduction

The Canadian Triage and Acuity Scale (CTAS) is the standard used in all Canadian and many international emergency departments (EDs) for establishing the priority by which patients should be assessed.<1-7> The intent is to identify patients with critical and time-sensitive conditions who should be seen expeditiously to initiate care that maximizes improved morbidity and mortality outcomes. The scale delineates 5 levels of acuity: level 1 (resuscitation), level 2 (emergent), level 3 (urgent), level 4 (less urgent) and level 5 (non-urgent).<8-11> CTAS is similar to other standardized triage algorithms including the Australasian Triage Scale <12> and the Manchester Triage Scale <13>, which categorize patients based on the time they may safely wait, but differs from other triage algorithms such as the Emergency Severity Index <14>, which is based on both patient acuity and the number of anticipated resources their care may require.

In addition to its clinical utility, CTAS has become an important administrative metric used by governments to estimate patient care requirements, determine ED funding and physician workload models.<15-18> However, despite its importance, the process by which CTAS scores are derived is highly variable.<4,5,16,17,19,20> According to an auditor's report in 2010, the process of triaging patients was found to vary significantly within and between Ontario hospitals, with 38% of ED patients under-triaged, and no process in place for government to validate submitted triage scores with a resulting lack of accountability for derived ED funding.<21> Recommendations were subsequently made and in 2015, the government agreed to fund the development and implementation of a standardized, electronic solution to reduce triage variability across the province.

eCTAS is a real time electronic decision-support tool, designed to improve patient safety and quality of care by standardizing the application of national triage guidelines.<22> The eCTAS system was based on the concept of the eTRIAGE algorithm reported by Dong et al.<23-25> In order to ensure an intuitive, user-friendly design, eCTAS was further informed by a comprehensive needs assessment and environmental scan, including 24 hospital site visits that included teaching, community, and rural EDs, and consultation with over 100 clinical and technical experts from across the province.

The application requires the user to select a presenting complaint from a standardized list of 170 complaints which then generates a complaint-specific triage template displaying all appropriate potential modifiers (i.e., vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) to assist the user in assigning the appropriate CTAS score in real time. Specifically, the application dynamically calculates a recommended CTAS score based on the presenting complaint, the patient's vital signs and selected clinical modifiers. Hospitals have multiple options for how they implement the solution, allowing them to choose the option that best suits their needs. They can use the provincial, clinically designed web application, or they can incorporate provincial CTAS decision support into their own hospital systems, designing and developing their own triage screens. As of April 2019, eCTAS has been implemented in over 95 (80%) EDs across the province.

Goals of This Investigation:

The goal of this study was to evaluate the implementation of eCTAS in a variety of ED settings. Specifically, the primary objective was to determine the interrater agreement of the triage score pre and post-implementation of eCTAS. Secondary objectives were to determine the triage time and accuracy pre and post-implementation of eCTAS. We hypothesized that interrater agreement and triage accuracy would be higher and triage time would be similar (within one minute) after the implementation of eCTAS.

Methods

Study design, setting and selection of participants:

This was a prospective, observational multicentered study conducted in seven hospital EDs in Ontario, Canada. A provincial steering committee selected the seven EDs included in this study from a pool of approximately 12 early adopter sites, selected to represent a mix of triage processes (electronic vs. manual), documentation practices (electronic vs. paper), hospital types (rural, community and teaching) and patient volumes (annual ED census ranged from 38,000 to 136,000). Prior to the start of the study, CTAS had been the standard triage process for all participating EDs for at least 15 years. All nurses observed in this study had at least 2 years of ED experience and had previously undertaken standard CTAS triage training (8-hour didactic session followed by 1-3 days of hands-on triage experience facilitated by a senior triage nurse) provided by a certified instructor.

Prior to the implementation of eCTAS, all triage nurses completed a mandatory 2-hour training session consisting of didactic teaching and application practice using an online, interactive, simulated training environment with 10 standardized triage scenarios and real-time instruction on how to incorporate vital signs and relevant modifiers. For ongoing eCTAS training, all triage nurses have access to a training environment as soon as they receive their access code and can continue to access this environment for future training and updates. When eCTAS updates are implemented, there is an education session in the form of a train the trainer that includes a full teaching module to allow hospital trainers to share the updates. There is also a help guide built into the eCTAS tool where a nurse can search any aspect of the tool and will get a visual guide to the section in question with a full training step by step guide, there are also videos in this section.

Methods of Measurement

Interobserver Assessments

To determine interrater agreement, a provincial CTAS auditor directly observed on-duty triage nurses in the ED, listened to the triage interaction and independently assigned a CTAS score in real time. The provincial CTAS auditor was not permitted to directly question the patient and both nurses were blinded to the other's assessment notes and triage score. The CTAS auditor was the current provincial master trainer for CTAS with 22 years of ED nursing and triage experience.

Each of the seven participating EDs was visited three times pre (July to September 2016) and three times post-eCTAS implementation (June 2017 to October 2018). Each hospital implemented eCTAS at different times which is why the post-eCTAS data collection period was so broad. The

same provincial auditor completed all interobserver assessments over seven-hour triage shifts on non-consecutive weekdays between 10am and 8pm. The time of day and non-consecutive days were chosen to maximize the number of patient encounters and the number of triage nurses observed. Triage nurse re-assessments of waiting room patients were not included in this validation study. Triage assessments missing either the start or end time were excluded. All post eCTAS implementation observations occurred after a minimum three-month stabilization period to allow ED triage nurses to become familiar with the eCTAS tool.

Triage Time Assessments

Separate from the interobserver assessments, trained research assistants recorded the time it took to triage patients in the same seven participating EDs pre and post implementation of eCTAS. Triage time was collected using a laptop computer equipped with Microsoft Excel (Microsoft Corporation, Redmond, Washington), customized with an automated electronic time stamp to record triage start and end times. The research assistants did not have any contact with patients and no patient information was collected, including the triage score. Prior to the start of data collection, all research assistants completed a mandatory three-hour training session consisting of didactic teaching on ED triage, process mapping of triage and registration flow, patient privacy and confidentiality. This was followed by at least one shift at a local ED where the research assistants directly observed a triage nurse and pilot time testing was conducted to ensure the validity of the software and become familiar with real-time ED flow.

Each of the seven participating EDs was visited 10 times pre (June to August 2016) and post eCTAS (August 2017 to December 2018) implementation for the triage time portion of the study. The research assistants observed triage nurses over six-hour shifts on weekdays between 10am and 8pm, selected to maximize the number of patient observations per shift. Triage re-assessments were not included. All post eCTAS implementation observations occurred after a minimum three-month stabilization period.

The study protocol was approved by the research ethics board at each participating institution. Triage nurse participation was voluntary. No triage nurse declined to participate. The study was funded by the Ontario Ministry of Health and Long-Term Care. The funding agreement ensured the investigators maintained control over the study design, methods and interpretation of the results.

Primary Data Analysis

Interrater agreement was estimated using unweighted, linear-weighted and quadratic-weighted kappa (k) statistics with 95% confidence intervals (CIs), with $k < 0.2$ interpreted as "poor agreement"; $k = 0.2$ to 0.4 interpreted as "fair agreement"; 0.41 to 0.60 interpreted as "moderate agreement"; $k = 0.61$ to 0.80 interpreted as "good agreement" and $k > 0.80$ interpreted as "very good agreement".<26,27> Exact modal agreement, under-triage and over-triage were calculated pre and post eCTAS implementation. Under-triage and over-triage were defined by nurse assignment to a triage level of lower or higher acuity than the provincial CTAS auditor, respectively. Mean percentage of accurate score assignment for all triage assessments was

calculated in aggregate and for each site separately. Triage time was defined as the time interval from first patient-triage nurse interaction to the time the triage assessment was completed and the patient left the triage station. Differences in median triage time pre and post implementation of eCTAS were assessed using the Mann-Whitney U test and are presented with 95% confidence intervals (CIs) according to the Hodges-Lehmann method. Proportional differences were estimated using chi-square statistics with 95% CIs. Data analyses were performed using Stata 15.0 (StataCorp LP, College Station, Texas).

Results

1491 (752 pre-eCTAS, 739 post-implementation) individual patient triage assessments were audited over 42 (21 pre-eCTAS, 21 post-implementation) seven-hour triage shifts. Exact modal agreement was achieved for 567 (75.4%) patients pre-eCTAS, compared to 685 (92.7%) patients triaged with eCTAS (Table 1). Improvements in accuracy were seen across all triage categories post-eCTAS implementation.

Table 1. Exact modal agreement, under-triage and over-triage pre and post-eCTAS implementation.

A. Pre-eCTAS

		CTAS Auditor					
Triage Nurse		1	2	3	4	5	Total
	1		4				4
	2	1	**124**	27	2		154
	3	1	27	**252**	44		324
	4		2	55	**173**	13	243
	5			2	7	**18**	27
	TOTAL	**2**	**157**	**336**	**226**	**31**	**752**
	Accuracy	**0%**	**79%**	**75%**	**76%**	**58%**	

B. Post-eCTAS

	CTAS Auditor						
Triage Nurse		1	2	3	4	5	Total
	1	**4**					4
	2		**164**	10		1	175
	3		3	**323**	14	6	346
	4		1	7	**137**	7	152
	5			1	4	**57**	62
	TOTAL	**4**	**168**	**341**	**155**	**71**	**739**
	Accuracy	**100%**	**98%**	**95%**	**88%**	**81%**	

The use of eCTAS significantly reduced the number of patients over-triaged (12.0% vs. 5.1%; Δ 6.9, 95% CI: 4.0 to 9.7) and under-triaged (12.6% vs. 2.2%; Δ 10.4, 95% CI: 7.9 to 13.2), and this was consistent across all participating sites (Table 2).

Table 2. Exact modal agreement, under triage and over triage pre and post-eCTAS implementation by hospital.

Hospital Type	Exact Modal Agreement (%)		Under Triaged (%)		Over Triaged (%)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Community	74.4	92.0	8.9	5.0	16.7	3.0
Academic	72.6	91.1	15.1	3.0	12.3	5.9
Community	76.7	92.5	12.3	1.1	11.0	6.4
Rural	72.8	96.1	11.6	0.0	15.5	3.9
Rural	73.4	91.7	18.3	4.6	8.3	3.7
Large Community	82.5	94.1	8.1	0.9	9.4	4.9
Large Community	71.8	91.7	15.5	0.0	12.7	8.3
Total	**75.4**	**92.7**	**12.6**	**2.2**	**12.0**	**5.1**

Where: Pre = pre-eCTAS implementation; Post = post-eCTAS implementation.

Pre-eCTAS, 18.5% of CTAS 2 and 17.0% CTAS 3 patients were under-triaged, and 20.4% of CTAS 4 and 41.9% of CTAS 5 patients were over-triaged. Post-eCTAS implementation, 2.4% of CTAS 2 (Δ 16.1%; 95% CI: 9.7 to 23.0) and 2.3% CTAS 3 (Δ 14.6%; 95% CI: 10.4 to 19.1) patients were under-triaged, and 9.0% of CTAS 4 (Δ 11.3%; 95% CI: 4.0 to 18.1) and 19.7% of CTAS 5 (Δ 22.2%; 95% CI: 3.4 to 41.1) patients were over-triaged.

Interrater agreement pre and post eCTAS implementation by hospital is shown in Table 3. Across all sites, interrater agreement was higher with eCTAS compared to pre-eCTAS. The aggregate unweighted kappa was 0.63 (95% CI: 0.58 to 0.68) pre-eCTAS compared to 0.89 (95% CI: 0.86 to 0.92) post-eCTAS implementation. Weighted analysis produced substantially higher estimates of reliability compared to unweighted analysis, with quadratic weighting resulting in higher interrater agreement compared to linear weighting (Table 3).

Research assistants recorded triage time during 140 (70 pre-eCTAS, 70 post-implementation) six-hour triage shifts. Triage time was captured for 3808 patients pre-eCTAS and for 3489 patients post implementation of eCTAS. Table 4 shows median triage time by hospital ED pre and post eCTAS implementation. Median triage time was 312 seconds pre-eCTAS compared to 347 seconds with eCTAS (Δ 35 seconds, 95% CI: 29 to 40 seconds). Four (57.1%) of the included sites used a paper-based triage method prior to eCTAS. When these sites implemented eCTAS, median triage time increased by 74 (67 to 81) seconds (Table 5). Of the three sites using an electronic-based triage process, median triage time decreased by 30 (17 to 44) seconds with the implementation of eCTAS.

Table 3. Interrater agreement pre and post-eCTAS implementation by hospital.

Hospital Type	Unweighted Kappa (95% CI)		Linear Weighted Kappa (95% CI)		Quadratic Weighted Kappa (95% CI)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Community	0.61 (0.47, 0.74)	0.88 (0.80, 0.96)	0.70 (0.60, 0.81)	0.90 (0.83, 0.97)	0.81 (0.54, 1.0)	0.92 (0.71, 1.0)
Academic	0.60 (0.50, 0.71)	0.87 (0.81, 0.94)	0.69 (0.60, 0.78)	0.90 (0.84, 0.96)	0.78 (0.55, 1.0)	0.92 (0.77, 1.0)
Community	0.64 (0.48, 0.79)	0.87 (0.78, 0.96)	0.71 (0.58, 0.84)	0.90 (0.83, 0.97)	0.79 (0.39, 1.0)	0.93 (0.72, 1.0)
Rural	0.56 (0.42, 0.70)	0.94 (0.88, 0.99)	0.63 (0.51, 0.76)	0.94 (0.89, 1.0)	0.73 (0.33, 1.0)	0.95 (0.76, 1.0)
Rural	0.57 (0.43, 0.70)	0.88 (0.81, 0.96)	0.62 (0.50, 0.74)	0.90 (0.84, 0.97)	0.69 (0.25, 1.0)	0.92 (0.73, 1.0)
Large Community	0.74 (0.65, 0.83)	0.90 (0.83, 0.9)	0.80 (0.73, 0.87)	0.93 (0.88, 0.98)	0.87 (0.69, 1.0)	0.96 (0.86, 1.0)
Large Community	0.55 (0.39, 0.72)	0.88 (0.79, 0.96)	0.62 (0.49, 0.76)	0.87 (0.77, 0.96)	0.71 (0.22, 1.0)	0.86 (0.51, 1.0)
Total	**0.63 (0.58, 0.68)**	**0.89 (0.86, 0.92)**	**0.71 (0.67, 0.74)**	**0.91 (0.88, 0.93)**	**0.79 (0.68, 0.91)**	**0.93 (0.85, 1.0)**

Where: CI: confidence interval; Pre = pre-eCTAS implementation; Post = post-eCTAS implementation.

Table 4. Median triage time by hospital pre and post-eCTAS implementation.

Hospital Type	Annual ED Volume	Previous Triage Method	Triage Process*	# Patients Pre	# Patients Post	Median (IQR) Triage Time (secs) Pre	Median (IQR) Triage Time (secs) Post	Δ 95% CI
Community	56,000	Paper	1-stage	440	335	332 (239, 446)	400 (308, 488)	68 (47, 88)
Academic	61,000	Paper	1-stage	582	503	262 (211, 344)	341 (264, 440)	79 (65, 93)
Community	74,000	Electronic	2-stage	472	582	449 (346, 647)	416 (288, 632)	-33 (-59, -8)
Rural	38,000	Electronic	1-stage	300	363	355 (272, 464)	312 (234, 465)	-43 (-66, -20)
Rural	45,000	Paper	1-stage	384	380	262 (208, 341)	345 (288, 446)	83 (78, 99)
Large Community	103,000	Paper	1-stage	804	808	231 (184, 288)	289 (233, 371)	58 (50, 67)
Large Community	136,000	Electronic	2-stage	826	518	416 (311, 552)	416 (295, 570)	0 (-20, 21)
Total				**3808**	**3489**	**312 (230, 347)**	**347 (263, 478)**	**35 (29, 40)**

Where: ED = emergency department; Pre = pre-eCTAS implementation; Post = post-eCTAS implementation; IQR = interquartile range; secs = seconds; CI = confidence interval; Δ = difference.

*1-stage triage: Triage nurse receives, triages and dispositions the patient to registration all in one encounter. 2-stage: one or more triage nurse receives the patient and determines the patient's ability to wait for triage (pre-triage). Those who cannot wait go directly to a second triage nurse for immediate assessment. Patients deemed eligible to wait remain in the triage area until a second triage nurse is available to complete the triage process.

Table 5. Median triage time by triage process pre and post-eCTAS implementation.

Previous Triage Method	# Patients Pre	# Patients Post	Median (IQR) Triage Time (secs) Pre	Median (IQR) Triage Time (secs) Post	Δ 95% CI
Paper	2210	2026	256 (201, 341)	330 (257, 424)	74 (67, 81)
Electronic	1598	1463	414 (312, 553)	384 (272, 570)	-30 (-44, -17)
1-stage	2510	2389	267 (207, 357)	329 (254, 426)	62 (55, 68)
2-stage	1298	1100	430 (324, 581)	416 (290, 607)	-14 (-28, -1)

Where: Pre = pre-eCTAS implementation; Post = post-eCTAS implementation; IQR = interquartile range; secs = seconds; CI = confidence interval.

Limitations

This study has several important limitations. All interobserver assessments and triage time assessments occurred during peak ED volumes (10am-6pm) Monday to Friday. No data was collected in the evening, overnight, early morning or weekend. It is possible that triage accuracy, variability and time may be different during these hours. Additionally, the majority of triage encounters observed in this study took place at the main triage station in the ED. This study captured few triage encounters for patients arriving to the ED by ambulance or in a non-monitored area, so we are unclear if the results are generalizable to those specific triage presentations. Additionally, very few triage encounters were captured for critically ill patients (CTAS 1), however, the concept of triage in these critically ill patients is rather moot as they often require immediate lifesaving intervention.

The CTAS auditor who completed all 1491 interobserver triage assessments was the provincial master trainer for CTAS with 22 years of ED nursing and triage experience. We are unsure if another CTAS auditor would have similar experience, potentially limiting the external validity of our triage accuracy findings. We did not record the triage experience of the nurses included in this study, so we are unable to comment how this may have influenced triage accuracy or time. However, a recent international multicentered study of 87 Emergency Severity Index (ESI)-trained nurses from Brazil, the United Arab Emirates, and the United States did not find any association between nursing experience and triage accuracy or performance.<28>

All EDs included in this study had at least 15 years of experience using CTAS. It is unknown if our results would be applicable to EDs using other triage systems such as the ESI<14>, Australasian Triage Scale<12>, or the Manchester Triage Scale.<13> The Hawthorne effect (also referred to as the observer effect) must also be considered when interpreting the study results. The triage nurses were aware they were being observed and understood the objective of the study, therefore, the presence of the CTAS auditor and the research assistants may have influenced their behavior. Finally, although our findings were consistent between seven institutions across the province, it is possible that other EDs using CTAS have significantly different triage accuracy and variability.

Discussion

This study evaluates the implementation of eCTAS, a real time electronic decision-support tool designed to improve patient safety and quality of care by standardizing the application of national triage guidelines. We found that interrater agreement and triage accuracy were higher across all seven included EDs, and median triage time was similar after the implementation of eCTAS.

When interpreting interrater agreement, it is important to consider the difference between unweighted and weighted kappa statistics. When we consider measurement scales that are ordinal, such as a 5-level triage scale, some argue it is important to retain the hierarchical nature of the categories and consider the magnitude of disagreement between observers. For example, the difference between one observer triaging a patient as a CTAS 5 and a second observer triaging the same patient as a CTAS 4 is small compared to the difference of the second observer triaging that

patient as a CTAS 1. Weighted kappa penalizes disagreements in terms of their discordance, whereas unweighted kappa treats all disagreements equally. Therefore, some have argued that weighted kappa statistics, specifically quadratic-weighted kappa, is more appropriate for ordinal scales.<29> However, others suggest the situation is different for triage, where there are only 5 possible triage levels and 99% of patients fall in the lowest 4 levels.<30,31> If one observer triages a patient as CTAS 3, the quadratic-weighted kappa will assign the second observer credit if they triage the patient as CTAS 2, CTAS 3 or CTAS 4. Weighted kappa scores overestimate the level of agreement between observers. Therefore, we chose to report raw agreement on exact triage level as well as unweighted, linear-weighted and quadradic-weighted kappa values.

Previous studies reporting interrater agreement have usually been based on paper-based case scenarios with mock patients. Beveridge et al., was one of the first to report interrater agreement using CTAS. Ten emergency physicians and ten nurses assigned triage scores based on 50 case scenarios and achieved a raw agreement of 54% with a weighted kappa value of 0.80 (95% CI: 0.79 to 0.81). When interrater agreement was examined for emergency nurses only, the kappa was 0.84 (95% CI: 0.83 to 0.85).<19> In a similar study, Manos et al., invited 20 emergency care providers to independently assign CTAS scores to 42 case scenarios. Exact modal agreement on triage level was 63.4%, agreement within one triage level was 94.9%, and the overall quadratic-weighted kappa was 0.77 (95% CI: 0.76 to 0.78).<32> Worster et al., compared inter-observer reliability between the ESI and CTAS using of 200 paper-based case scenarios. The quadratic-weighted kappa of the CTAS group was 0.91 (95% CI: 0.90 to 0.99), which was similar to the ESI group (0.89; 95% CI: 0.88 to 0.99).<29>

In 2003, Grafstein et al., reported the interrater reliability of a computer-linked triage system using CTAS in real-time.<33> Two triage nurses, blinded to each other's triage assignment, assigned a CTAS score in real time using the computer-based system. Exact modal agreement was achieved in 74% of cases and within one CTAS level in 94% of cases. The unweighted kappa value was 0.66 (95% CI: 0.60 to 0.73), and the quadratic-weighted kappa was 0.75 (95% CI: 0.68 to 0.81).<33>

In 2006, Dong et al., examined interrater agreement in a prospective, real-time study between two groups of experienced triage nurses using eTRIAGE, a Canadian developed, web-based triage decision support tool based on CTAS.<24> Consecutive ED patients were assessed by the duty triage nurse and an independent study nurse, blinded to each other's assessments and triage assignments, both using eTRIAGE. A total of 569 patients were included and linear-weighted kappa was "moderate" 0.52 (95% CI: 0.46 to 0.57) and "good" with quadratic-weighted kappa (0.66; 95% CI: 0.60 to 0.71). Other computer-assisted triage systems have been reported.<25>

More recently, Dugas et al., published the derivation and validation of a computer-based electronic triage system using the ESI and concluded that compared to ESI, the electronic triage system may reduce subjectivity in triage evaluation, while more evenly distributing patients among lower-acuity levels. However, prospective evaluation is required to fully understand its clinical utility and generalizability. <34>

At the time of the study, only 12 of the approximately 130 EDs in the province were still using a paper-based triage method, and 4 of them were included in this study. When these sites implemented eCTAS, median triage time increased by 74 seconds. However, EDs using an electronic-based triage process prior to eCTAS implementation had a decrease in median triage time by 30 seconds following the implementation of eCTAS. Although the overall median triage time increased by 35 seconds, we suspect this is an overestimate of what will happen across the province when the remaining EDs using an electronic platform implement the eCTAS system. Moreover, as nurses gain experience with the eCTAS system, they will likely improve their triage speed without sacrificing accuracy.

Given that CTAS is used to define ED case-mix groups for comparative and benchmarking processes, reporting agreement on exact triage level is important. In addition to its clinical utility, CTAS has become an important administrative metric used by governments to estimate patient care requirements and determine ED funding and physician workload models. In Ontario, approximately 85% of EDs with more than 27,500 annual visits are funded through a formula according to their ED patient volume and acuity case-mix, based on CTAS scores.<16,17>

Electronic decision support tools, such as eCTAS, have been designed to improve triage reliability and reduce variability while respecting the autonomy of nursing clinical judgement. The eCTAS application requires the user to select a presenting complaint from a standardized list of 170 complaints, which then displays a CTAS-based template with complaint-specific modifiers sorted from highest to lowest acuity to support the assignment of the appropriate triage level. If the user's

clinical judgment differs from the eCTAS generated score, the user can override the eCTAS score upwards and provide an explanation (i.e., impression of higher acuity). Assigning a lower acuity score than eCTAS recommends is not permitted.

In this study, there was marked improvement in triage accuracy across all seven sites after eCTAS implementation (aggregate unweighted kappa was 0.63 pre-eCTAS compared to 0.89 post-eCTAS). The use of eCTAS significantly reduced the number of patients over-triaged and under-triaged, and this was consistent across all participating sites. However, after the implementation of eCTAS, 9% of CTAS 4 patients and nearly 20% of CTAS 5 patients were assigned a triage score higher than the score suggested by eCTAS, suggesting eCTAS alone may not be able to identify potentially relevant comorbidity or complexity in this population. The CTAS National Working Group has consistently advocated that nurse judgment must be included in the final assignment of the triage score.<9-11> Further study focusing on user over-rides to determine whether they are related to specific complaints, populations, clinical impression, user bias or inconsistencies in CTAS would be useful to optimize eCTAS, triage education and guide future enhancements.

As emergency care continues to demand higher efficiency to manage increasing ED volumes and patient complexity, there is a need for a timely, accurate and reliable triage system to provide safe and optimal care. The implementation of eCTAS, a standardized, electronic approach to performing triage assessments, improves both interrater agreement and data accuracy without substantially increasing triage time.

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Author Contributions: SLM, NM, HO, MB, BHR, JD and BB conceived the study and designed the protocol. HO and JG secured research resources and support. SLM, NM, SS, and BB supervised the conduct of the study and data collection. SLM, JM, TA, NM, SS and BB undertook recruitment of participating centers and patients and managed the data, including quality control. SLM provided statistical advice on study design and analyzed the data; NM and BB chaired the data oversight committee. KG, HO, MB, BHR, JD and BB provided clinical advice on study interpretation. SLM drafted the manuscript, and all authors contributed substantially to its revision. SLM takes responsibility for the paper as a whole.

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GENERAL MEDICINE/ORIGINAL RESEARCH

Interrater Reliability, Accuracy, and Triage Time Pre- and Post-implementation of a Real-Time Electronic Triage Decision-Support Tool

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Study objective: The electronic Canadian Triage and Acuity Scale (eCTAS) is a real-time electronic triage decision-support tool designed to improve patient safety and quality of care by standardizing the application of the Canadian Triage and Acuity Scale (CTAS). The objective of this study is to determine interrater agreement of triage scores pre- and post-implementation of eCTAS.

Methods: This was a prospective, observational study conducted in 7 emergency departments (EDs), selected to represent a mix of triage documentation practices, hospital types, and patient volumes. A provincial CTAS auditor observed triage nurses in the ED pre- and post-implementation of eCTAS and assigned an independent CTAS score in real time. Research assistants independently recorded triage time. Interrater agreement was estimated with κ statistics with 95% confidence intervals (CIs).

Results: A total of 1,491 individual triage assessments (752 pre-eCTAS, 739 post-implementation) were audited during 42 7-hour triage shifts (21 pre-eCTAS, 21 post-implementation). Exact modal agreement was achieved for 567 patients (75.4%) pre-eCTAS compared with 685 patients (92.7%) triaged with eCTAS. With the auditor's CTAS score as the reference, eCTAS significantly reduced the number of patients over-triaged (12.0% versus 5.1%; Δ 6.9; 95% CI 4.0 to 9.7) and under-triaged (12.6% versus 2.2%; Δ 10.4; 95% CI 7.9 to 13.2). Interrater agreement was higher with eCTAS (unweighted κ 0.89 versus 0.63; quadratic-weighted κ 0.93 versus 0.79). Median triage time was 312 seconds (n=3,808 patients) pre-eCTAS and 347 seconds (n=3,489 patients) with eCTAS (Δ 35 seconds; 95% CI 29 to 40 seconds).

Conclusion: A standardized, electronic approach to performing triage assessments improves both interrater agreement and data accuracy without substantially increasing triage time. [Ann Emerg Med. 2020;75:524-531.]

Please see page 525 for the Editor's Capsule Summary of this article.

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INTRODUCTION

The Canadian Triage and Acuity Scale (CTAS) is the standard used in all Canadian and many international emergency departments (EDs) for establishing the priority by which patients should be assessed.[1-7] The intent is to identify patients with critical and time-sensitive conditions who should be seen expeditiously to initiate care that maximizes improved morbidity and mortality outcomes. The scale delineates 5 levels of acuity: 1 (resuscitation), 2 (emergency), 3 (urgent), 4 (less urgent), and 5 (non-urgent).[8-11] CTAS is similar to other standardized triage algorithms, including the Australasian Triage Scale[12] and the Manchester Triage Scale,[13] which categorize patients according to the time they may safely wait, but differs from other triage algorithms such as the Emergency Severity Index (ESI),[14] which is based on both patient acuity and the number of anticipated resources their care may require.

In addition to its clinical utility, CTAS has become an important administrative metric used by governments to estimate patient care requirements and determine ED funding and physician workload models.[15-18] However, despite its importance, the process by which CTAS scores are derived is highly variable.[4,5,16,17,19,20] According to an auditor's report in 2010, the process of triaging patients was found to vary significantly within and between Ontario hospitals, with 38% of ED patients under-triaged and no process in place for government to validate submitted triage scores, with a resulting lack of accountability for derived ED funding.[21]

Editor's Capsule Summary

What is already known on this topic

Triage is a variable process but at times results in over- and undertriage.

What question this study addressed

Can the addition of electronic decision support improve the consistency of triage assessment with the Canadian Triage and Acuity Scale?

What this study adds to our knowledge

In this before-and-after study at 7 Canadian emergency departments of various types, electronic clinical decision support improved interrater triage agreement, with a variable effect on triage times.

How this is relevant to clinical practice

This study suggests that triage may be an appropriate process for clinical decision support. The study's methodology frames an observation-based approach for assessing triage accuracy.

Recommendations were subsequently made, and in 2015, the government agreed to fund the development and implementation of a standardized, electronic solution to reduce triage variability across the province.

The electronic Canadian Triage and Acuity Scale (eCTAS) is a real-time electronic decision-support tool, designed to improve patient safety and quality of care by standardizing the application of national triage guidelines.[22] The eCTAS system was based on the concept of the eTRIAGE algorithm reported by Dong et al.[23-25] To ensure an intuitive, user-friendly design, eCTAS was further informed by a comprehensive needs assessment and environmental scan, including 24 hospital site visits that included teaching, community, and rural EDs, and consultation with more than 100 clinical and technical experts from across the province.

The application requires the user to select a presenting complaint from a standardized list of 170 complaints, which then generates a complaint-specific triage template displaying all appropriate potential modifiers (ie, vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) to assist the user in assigning the appropriate CTAS score in real time. Specifically, the application dynamically calculates a recommended CTAS score based on the presenting complaint, the patient's vital signs, and selected clinical modifiers. Hospitals have multiple options for how they implement the solution, allowing them to choose the option that best suits their needs. They can use the provincial, clinically designed Web application, or they can incorporate provincial CTAS decision support into their own hospital systems, designing and developing their own triage screens. As of April 2019, eCTAS has been implemented in greater than 95 EDs (80%) across the province.

Goals of This Investigation

The goal of this study was to evaluate the implementation of eCTAS in a variety of ED settings. Specifically, the primary objective was to determine the interrater agreement of the triage score pre- and post-implementation of eCTAS. Secondary objectives were to determine the triage time and accuracy pre- and post-implementation of eCTAS. We hypothesized that interrater agreement and triage accuracy would be higher and triage time would be similar (within 1 minute) after the implementation of eCTAS.

MATERIALS AND METHODS

Study Design, Setting, and Selection of Participants

This was a prospective, observational, multicenter study conducted in 7 hospital EDs in Ontario, Canada. A provincial steering committee selected the 7 EDs included in this study from a pool of approximately 12 early-adopter sites, selected to represent a mix of triage processes (electronic versus manual), documentation practices (electronic versus paper), hospital types (rural, community, and teaching), and patient volumes (annual ED census ranged from 38,000 to 136,000). Before the start of the study, CTAS had been the standard triage process for all participating EDs for at least 15 years. All nurses observed in this study had at least 2 years of ED experience and had previously undertaken standard CTAS triage training (8-hour didactic session followed by 1 to 3 days of hands-on triage experience facilitated by a senior triage nurse) provided by a certified instructor.

Before the implementation of eCTAS, all triage nurses completed a mandatory 2-hour training session consisting of didactic teaching and application practice using an online, interactive, simulated training environment with 10 standardized triage scenarios and real-time instruction on how to incorporate vital signs and relevant modifiers. For ongoing eCTAS training, all triage nurses have access to a training environment as soon as they receive their access code and can continue to access this environment for future training and updates. When eCTAS updates are implemented, there is an education session in the form of a

"train the trainer" that includes a full teaching module to allow hospital trainers to share the updates. There is also a help guide built into the eCTAS tool, where a nurse can search any aspect of the tool and will get a visual guide to the section in question, with a full-training step-by-step guide; there are also videos in this section.

Methods of Measurement

To determine interrater agreement, a provincial CTAS auditor directly observed on-duty triage nurses in the ED, listened to the triage interaction, and independently assigned a CTAS score in real time. The provincial CTAS auditor was not permitted to directly question the patient, and both nurses were blinded to the other's assessment notes and triage score. The CTAS auditor was the current provincial master trainer for CTAS, with 22 years of ED nursing and triage experience.

Each of the 7 participating EDs was visited 3 times before eCTAS implementation (July to September 2016) and 3 times afterward (June 2017 to October 2018). Each hospital implemented eCTAS at different times, which is why the post-eCTAS data collection period was so broad. The same provincial auditor completed all interobserver assessments during 7-hour triage shifts on non-consecutive weekdays between 10 AM and 8 PM. The time of day and non-consecutive days were chosen to maximize the number of patient encounters and the number of triage nurses observed. Triage nurse reassessments of waiting room patients were not included in this validation study. Triage assessments missing either the start or end time were excluded. All post-eCTAS implementation observations occurred after a minimum 3-month stabilization period to allow ED triage nurses to become familiar with the eCTAS tool.

Separate from the interobserver assessments, trained research assistants recorded the time it took to triage patients in the same 7 participating EDs pre- and post-implementation of eCTAS. Triage time was collected with a laptop computer equipped with Microsoft Excel (version 2013; Microsoft, Redmond, WA), customized with an automated electronic time stamp to record triage start and end times. The research assistants did not have any contact with patients and no patient information was collected, including the triage score. Before the start of data collection, all research assistants completed a mandatory 3-hour training session consisting of didactic teaching on ED triage, process mapping of triage and registration flow, patient privacy, and confidentiality. This was followed by at least one shift at a local ED, in which the research assistants directly observed a triage nurse and pilot time testing was conducted to ensure the validity of the software and provide familiarity with real-time ED flow.

Each of the 7 participating EDs was visited 10 times before eCTAS implementation (June to August 2016) and afterward (August 2017 to December 2018) for the triage time portion of the study. The research assistants observed triage nurses during 6-hour shifts on weekdays between 10 AM and 8 PM, selected to maximize the number of patient observations per shift. Triage reassessments were not included. All post-eCTAS implementation observations occurred after a minimum 3-month stabilization period.

The study protocol was approved by the research ethics board at each participating institution. Triage nurse participation was voluntary. No triage nurse declined to participate.

Primary Data Analysis

Interrater agreement was estimated using unweighted, linear-weighted, and quadratic-weighted κ statistics with 95% confidence intervals (CIs), with $\kappa<0.2$ interpreted as poor agreement, $\kappa=0.2$ to 0.4 interpreted as fair agreement, $\kappa=0.41$ to 0.60 interpreted as moderate agreement, $\kappa=0.61$ to 0.80 interpreted as good agreement, and $\kappa>0.80$ interpreted as very good agreement.[26,27] Exact modal agreement, under-triage, and over-triage were calculated pre- and post-eCTAS implementation. Under-triage and over-triage were defined by nurse assignment to a triage level of lower or higher acuity than the provincial CTAS auditor assignment, respectively. Mean percentage of accurate score assignment for all triage assessments was calculated in aggregate and for each site separately. Triage time was defined as the interval from first patient–triage nurse interaction to the time the triage assessment was completed and the patient left the triage station. Differences in median triage time pre- and post-implementation of eCTAS were assessed with the Mann-Whitney *U* test and are presented with 95% CIs according to the Hodges-Lehmann method. Proportional differences were estimated with χ^2 statistics with 95% CIs. Data analyses were performed with Stata (version 15.0; StataCorp, College Station, TX).

RESULTS

A total of 1,491 individual patient triage assessments (752 pre-eCTAS, 739 post-implementation) were audited during 42 7-hour triage shifts (21 pre-eCTAS, 21 post-implementation). Exact modal agreement was achieved for 567 patients (75.4%) pre-eCTAS compared with 685 patients (92.7%) triaged with eCTAS (Table 1). Improvements in accuracy were observed across all triage

Table 1. Exact modal agreement, under-triage, and over-triage pre- and post-eCTAS implementation.

***A*, Pre-eCTAS**

		CTAS Auditor					
		1	2	3	4	5	Total
Triage Nurse	1		4				4
	2	1	**124**	27	2		154
	3	1	27	**252**	44		324
	4		2	55	**173**	13	243
	5			2	7	**18**	27
	Total	2	157	336	226	31	752
	Accuracy	0%	79%	75%	76%	58%	

***B*, Post-eCTAS**

		CTAS Auditor					
		1	2	3	4	5	Total
Triage Nurse	1	**4**					4
	2		**164**	10		1	175
	3		3	**323**	14	6	346
	4		1	7	**137**	7	152
	5			1	4	**57**	62
	Total	4	168	341	155	71	739
	Accuracy	100%	98%	95%	88%	81%	

categories post-eCTAS implementation. The use of eCTAS significantly reduced the number of patients over-triaged (12.0% versus 5.1%; Δ 6.9; 95% CI 4.0 to 9.7) and under-triaged (12.6% versus 2.2%; Δ 10.4; 95% CI 7.9 to 13.2), and this was consistent across all participating sites (Table 2). Pre-eCTAS, 18.5% of CTAS level 2 and 17.0% of CTAS level 3 patients were under-triaged, and 20.4% of CTAS level 4 and 41.9% of CTAS level 5 patients were over-triaged. Post-eCTAS implementation, 2.4% of CTAS level 2 patients (Δ 16.1%; 95% CI 9.7% to 23.0%) and 2.3% of CTAS level 3 patients (Δ 14.6%; 95% CI 10.4% to 19.1%) were under-triaged, and 9.0% of CTAS level 4 patients (Δ 11.3%; 95% CI 4.0% to 18.1%) and 19.7% of CTAS level 5 patients (Δ 22.2%; 95% CI 3.4% to 41.1%) were over-triaged.

Table 2. Exact modal agreement, under-triage, and over-triage pre- and post-eCTAS implementation by hospital.

	Exact Modal Agreement, %		Undertriaged, %		Overtriaged, %	
Hospital Type	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Community	74.4	92.0	8.9	5.0	16.7	3.0
Academic	72.6	91.1	15.1	3.0	12.3	5.9
Community	76.7	92.5	12.3	1.1	11.0	6.4
Rural	72.8	96.1	11.6	0.0	15.5	3.9
Rural	73.4	91.7	18.3	4.6	8.3	3.7
Large community	82.5	94.1	8.1	0.9	9.4	4.9
Large community	71.8	91.7	15.5	0.0	12.7	8.3
Total	75.4	92.7	12.6	2.2	12.0	5.1

Pre, Pre-eCTAS implementation; *post*, post-eCTAS implementation.

Interrater agreement pre- and post-eCTAS implementation by hospital is shown in Table 3. Across all sites, interrater agreement was higher with eCTAS compared with pre-eCTAS. The aggregate unweighted κ was 0.63 (95% CI 0.58 to 0.68) pre-eCTAS compared with 0.89 (95% CI 0.86 to 0.92) post-eCTAS implementation. Weighted analysis produced substantially higher estimates of reliability compared with unweighted analysis, with quadratic weighting resulting in higher interrater agreement compared with linear weighting (Table 3).

Research assistants recorded triage time during 140 (70 pre-eCTAS, 70 post-implementation) 6 hour triage shifts. Triage time was captured for 3,808 patients pre-eCTAS and for 3,489 post-implementation of eCTAS. Table 4 shows median triage time by hospital ED pre- and post-eCTAS implementation. Median triage time was 312 seconds pre-eCTAS compared with 347 seconds with eCTAS (Δ 35 seconds; 95% CI 29 to 40 seconds). Four of the included sites (57.1%) used a paper-based triage method before eCTAS. When these sites implemented eCTAS, median triage time increased by 74 seconds (95% CI, 67 to 81 seconds) (Table 5). Of the 3 sites using an electronic-based triage process, median triage time decreased by 30 seconds (95% CI, 17 to 44 seconds) with the implementation of eCTAS.

LIMITATIONS

This study has several important limitations. All interobserver assessments and triage time assessments occurred during peak ED volumes (10 AM to 6 PM) Monday to Friday. No data were collected in the evening, overnight, in the early morning, or during the weekend. It is possible that triage accuracy, variability, and time are different during these hours. Additionally, the majority of triage encounters observed in this study took place at the main triage station in the ED. This study captured few triage encounters for patients arriving to the ED by ambulance or in an unmonitored area, so we are unsure whether the results are generalizable to those specific triage presentations. Additionally, few triage encounters were captured for critically ill patients (CTAS level 1); however, the concept of triage for these critically ill patients is moot because they often require immediate lifesaving intervention. The CTAS auditor who completed all 1,491 interobserver triage assessments was the provincial master trainer for CTAS, with 22 years of

Table 3. Interrater agreement pre- and post-eCTAS implementation by hospital.

	Unweighted κ (95% CI)		Linear Weighted κ (95% CI)		Quadratic Weighted κ (95% CI)	
Hospital Type	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Community	0.61 (0.47–0.74)	0.88 (0.80–0.96)	0.70 (0.60–0.81)	0.90 (0.83–0.97)	0.81 (0.54–1.0)	0.92 (0.71–1.0)
Academic	0.60 (0.50–0.71)	0.87 (0.81–0.94)	0.69 (0.60–0.78)	0.90 (0.84–0.96)	0.78 (0.55–1.0)	0.92 (0.77–1.0)
Community	0.64 (0.48–0.79)	0.87 (0.78–0.96)	0.71 (0.58–0.84)	0.90 (0.83–0.97)	0.79 (0.39–1.0)	0.93 (0.72–1.0)
Rural	0.56 (0.42–0.70)	0.94 (0.88–0.99)	0.63 (0.51–0.76)	0.94 (0.89–1.0)	0.73 (0.33–1.0)	0.95 (0.76–1.0)
Rural	0.57 (0.43–0.70)	0.88 (0.81–0.96)	0.62 (0.50–0.74)	0.90 (0.84–0.97)	0.69 (0.25–1.0)	0.92 (0.73–1.0)
Large community	0.74 (0.65–0.83)	0.90 (0.83–0.9)	0.80 (0.73–0.87)	0.93 (0.88–0.98)	0.87 (0.69–1.0)	0.96 (0.86–1.0)
Large community	0.55 (0.39–0.72)	0.88 (0.79–0.96)	0.62 (0.49–0.76)	0.87 (0.77–0.96)	0.71 (0.22–1.0)	0.86 (0.51–1.0)
Total	0.63 (0.58–0.68)	0.89 (0.86–0.92)	0.71 (0.67–0.74)	0.91 (0.88–0.93)	0.79 (0.68–0.91)	0.93 (0.85–1.0)

ED nursing and triage experience. We are unsure whether another CTAS auditor would have similar experience, potentially limiting the external validity of our triage accuracy findings. We did not record the triage experience of the nurses included in this study, so we are unable to comment on how this may have influenced triage accuracy or time. However, a recent international multicenter study of 87 ESI-trained nurses from Brazil, the United Arab Emirates, and the United States did not find any association between nursing experience and triage accuracy or performance.[28] All EDs included in this study had at least 15 years of experience using CTAS. It is unknown whether our results would be applicable to EDs using other triage systems such as the ESI,[14] Australasian Triage Scale,[12] or the Manchester Triage Scale.[13] The Hawthorne effect (also referred to as the observer effect) must also be considered when the study results are interpreted. The triage nurses were aware they were being observed and understood the objective of the study; therefore, the presence of the CTAS auditor and the research assistants may have influenced their behavior. Finally, although our findings were consistent between 7 institutions across the province, it is possible that other EDs using CTAS have significantly different triage accuracy and variability.

DISCUSSION

This study evaluates the implementation of eCTAS, a real-time electronic decision-support tool designed to improve patient safety and quality of care by standardizing the application of national triage guidelines. We found that interrater agreement and triage accuracy were higher across all 7 included EDs, and median triage time was similar after the implementation of eCTAS.

When interrater agreement is interpreted, it is important to consider the difference between unweighted and weighted κ statistics. When measurement scales that are ordinal are considered, such as a 5-level triage scale, some

Table 4. Median triage time by hospital pre- and post-eCTAS implementation.

Hospital Type	Annual ED Volume	Previous Triage Method	Triage Process, No. of Stages*	No. of Patients Pre	No. of Patients Post	Median (IQR) Triage Time Pre, Seconds	Median (IQR) Triage Time Post, Seconds	Δ 95% CI
Community	56,000	Paper	1	440	335	332 (239 to 446)	400 (308 to 488)	68 (47 to 88)
Academic	61,000	Paper	1	582	503	262 (211 to 344)	341 (264 to 440)	79 (65 to 93)
Community	74,000	Electronic	2	472	582	449 (346 to 647)	416 (288 to 632)	−33 (−59 to −8)
Rural	38,000	Electronic	1	300	363	355 (272 to 464)	312 (234 to 465)	−43 (−66 to −20)
Rural	45,000	Paper	1	384	380	262 (208 to 341)	345 (288 to 446)	83 (78 to 99)
Large community	103,000	Paper	1	804	808	231 (184 to 288)	289 (233 to 371)	58 (50 to 67)
Large community	136,000	Electronic	2	826	518	416 (311 to 552)	416 (295 to 570)	0 (−20 to 21)
Total				3,808	3,489	312 (230 to 347)	347 (263 to 478)	35 (29 to 40)

IQR, Interquartile range.

*One-stage triage: Triage nurse receives, triages, and dispositions the patient to registration all in one encounter. Two-stage: one or more triage nurses receive the patient and determine his or her ability to wait for triage (pretriage). Patients who cannot wait go directly to a second triage nurse for immediate assessment. Patients deemed eligible to wait remain in the triage area until a second triage nurse is available to complete the triage process.

Table 5. Median triage time by triage process pre- and post-eCTAS implementation.

Previous Triage Method	No. of Patients Pre	No. of Patients Post	Median (IQR) Triage Time Pre, Seconds	Median (IQR) Triage Time Post, Seconds	Δ 95% CI
Paper	2,210	2,026	256 (201 to 341)	330 (257 to 424)	74 (67 to 81)
Electronic	1,598	1,463	414 (312 to 553)	384 (272 to 570)	−30 (−44 to −17)
1-stage	2,510	2,389	267 (207 to 357)	329 (254 to 426)	62 (55 to 68)
2-stage	1,298	1,100	430 (324 to 581)	416 (290 to 607)	−14 (−28 to −1)

individuals argue it is important to retain the hierarchic nature of the categories and consider the magnitude of disagreement between observers. For example, the difference between one observer triaging a patient as a CTAS level 5 and a second observer triaging the same patient as a CTAS level 4 is small compared with the difference of the second observer triaging that patient as a CTAS level 1. Weighted κ penalizes disagreements in terms of their discordance, whereas unweighted κ treats all disagreements equally. Therefore, some individuals have argued that weighted κ statistics, specifically quadratic-weighted κ, are more appropriate for ordinal scales.[29] However, others suggest the situation is different for triage, in which there are only 5 possible triage levels and 99% of patients are in the lowest 4 levels.[30,31] If one observer triages a patient as CTAS level 3, the quadratic-weighted κ will assign the second observer credit if he or she triages the patient as CTAS level 2, 3, or 4. Weighted κ scores overestimate the level of agreement between observers. Therefore, we chose to report raw agreement on exact triage level, as well as unweighted, linear-weighted, and quadratic-weighted κ values.

Previous studies reporting interrater agreement have usually been based on paper-based case scenarios with mock patients. Beveridge et al[19] were some of the first to report interrater agreement with CTAS. Ten emergency physicians and 10 nurses assigned triage scores based on 50 case scenarios and achieved a raw agreement of 54%, with a weighted κ value of 0.80 (95% CI 0.79 to 0.81). When interrater agreement was examined for emergency nurses only, the κ was 0.84 (95% CI 0.83 to 0.85). In a similar study, Manos et al[32] invited 20 emergency care providers to independently assign CTAS scores to 42 case scenarios. Exact modal agreement on triage level was 63.4%, agreement within 1 triage level was 94.9%, and the overall quadratic-weighted κ was 0.77 (95% CI 0.76 to 0.78). Worster et al[29] compared interobserver reliability between the ESI and CTAS, using 200 paper-based case scenarios. The quadratic-weighted κ of the CTAS group was 0.91 (95% CI 0.90 to 0.99), which was similar to that of the ESI group (0.89; 95% CI 0.88 to 0.99).

In 2003, Grafstein et al[33] reported the interrater reliability of a computer-linked triage system using CTAS in real time. Two triage nurses, blinded to each other's triage assignment, assigned a CTAS score in real time, using the computer-based system. Exact modal agreement was achieved in 74% of cases and within 1 CTAS level in 94% of cases. The unweighted κ value was 0.66 (95% CI 0.60 to 0.73), and the quadratic-weighted κ was 0.75 (95% CI 0.68 to 0.81). In 2006, Dong et al[24] examined interrater agreement in a prospective, real-time study between 2 groups of experienced triage nurses using eTRIAGE, a Canadian-developed, Web-based triage decision-support tool based on CTAS. Consecutive ED patients were assessed by the duty triage nurse and an independent study nurse, blinded to each other's assessments and triage assignments, both using eTRIAGE. A total of 569 patients were included and linear-weighted κ was moderate (0.52; 95% CI 0.46 to 0.57) and quadratic-weighted κ was good (0.66; 95% CI 0.60 to 0.71). Other computer-assisted triage systems have been reported.[25]

More recently, Dugas et al[34] published the derivation and validation of a computer-based electronic triage system using the ESI and concluded that compared with ESI, the electronic triage system may reduce subjectivity in triage evaluation while more evenly distributing patients among lower-acuity levels. However, prospective evaluation is required to fully understand its clinical utility and generalizability.

At the study, only 12 of the approximately 130 EDs in the province were still using a paper-based triage method, and 4 of them were included in this study. When these sites implemented eCTAS, median triage time increased by 74 seconds. However, EDs using an electronic-based triage process before eCTAS implementation had a decrease in median triage time by 30 seconds after the implementation of eCTAS. Although the overall median triage time increased by 35 seconds, we suspect this is an overestimate of what will happen across the province when the remaining EDs using an electronic platform implement the eCTAS system. Moreover, as nurses gain experience with

the eCTAS system, they will likely improve their triage speed without sacrificing accuracy.

Given that CTAS is used to define ED case-mix groups for comparative and benchmarking processes, reporting agreement on exact triage level is important. In addition to its clinical utility, CTAS has become an important administrative metric used by governments to estimate patient care requirements and determine ED funding and physician workload models. In Ontario, approximately 85% of EDs with more than 27,500 annual visits are funded through a formula according to their ED patient volume and acuity case mix, based on CTAS scores.[16,17] Electronic decision-support tools, such as eCTAS, have been designed to improve triage reliability and reduce variability while respecting the autonomy of nursing clinical judgment. The eCTAS application requires the user to select a presenting complaint from a standardized list of 170 complaints, which then displays a CTAS-based template with complaint-specific modifiers sorted from highest to lowest acuity to support the assignment of the appropriate triage level. If the user's clinical judgment differs from the eCTAS-generated score, the user can override the eCTAS score and move it upward, and provide an explanation (ie, impression of higher acuity). Assigning a lower acuity score than eCTAS recommends is not permitted.

In this study, there was marked improvement in triage accuracy across all 7 sites after eCTAS implementation (aggregate unweighted κ was 0.63 pre-eCTAS compared with 0.89 post-eCTAS). The use of eCTAS significantly reduced the number of patients over- and under-triaged, and this was consistent across all participating sites. However, after the implementation of eCTAS, 9% of CTAS level 4 patients and nearly 20% of CTAS level 5 patients were assigned a triage score higher than the score suggested by eCTAS, suggesting eCTAS alone may not be able to identify potentially relevant comorbidity or complexity in this population. The CTAS National Working Group has consistently advocated that nurse judgment be included in the final assignment of the triage score.[9-11] Further study focusing on user overrides to determine whether they are related to specific complaints, populations, clinical impression, user bias, or inconsistencies in CTAS would be useful to optimize eCTAS and triage education, and to guide future enhancements.

Because emergency care continues to demand higher efficiency to manage increasing ED volumes and patient complexity, there is a need for a timely, accurate, and reliable triage system to provide safe and optimal care. The implementation of eCTAS, a standardized electronic approach to performing triage assessments, improves both interrater agreement and data accuracy without substantially increasing triage time.

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Author contributions: SLM, NM, HO, MB, BHR, JD, and BB conceived the study and designed the protocol. HO and JG secured research resources and support. SLM, NM, SS, and BB supervised the conduct of the study and data collection. SLM, JM, TA, NM, SS, and BB undertook recruitment of participating centers and patients and managed the data, including quality control. SLM provided statistical advice on study design and analyzed the data. NM and BB chaired the data oversight committee. KG, HO, MB, BHR, JD, and BB provided clinical advice on study interpretation. SLM drafted the article, and all authors contributed substantially to its revision. SLM takes responsibility for the paper as a whole.

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CHAPTER 3: CONSISTENCY OF TRIAGE SCORES BY PRESENTING COMPLAINT PRE AND POST-IMPLEMENTATION OF A REAL TIME ELECTRONIC TRIAGE DECISION-SUPPORT TOOL.

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ABSTRACT

Objective: eCTAS is a real-time electronic decision-support tool designed to standardize the application of the Canadian Triage and Acuity Scale (CTAS). This study addresses the variability of CTAS score distributions across institutions pre and post-eCTAS implementation.

Methods: We used population-based administrative data from 2016 to 2018 from all emergency departments (EDs) that had implemented eCTAS for 9 months. Following a 3-month stabilization period, we compared 6 months post-eCTAS data to the same 6 months the previous year (pre-eCTAS). We included triage encounters of adult (≥17 years) patients who presented with one of 16 pre-specified, high-volume complaints. For each ED, pre and post-eCTAS consistency was calculated as the absolute difference in CTAS distribution compared to the overall distribution of all included EDs, for each presenting complaint. Pre-eCTAS and post-eCTAS change scores were compared using a paired-samples t-test. We also assessed if eCTAS modifiers were associated with triage consistency.

Results: There were 363,214 (183,231 pre-eCTAS, 179,983 post-eCTAS) triage encounters included from 35 EDs. Triage scores were more consistent ($p<0.05$) post-eCTAS for six (37.5%) presenting complaints: chest pain (cardiac features), extremity weakness/symptoms of cerebrovascular accident, fever, shortness of breath, syncope, and hyperglycemia. Triage consistency was similar pre and post-eCTAS for altered level of consciousness, anxiety/situational crisis, confusion, depression/suicidal/deliberate self-harm, general weakness, head injury, palpitations, seizure, substance misuse/intoxication and vertigo. Use of eCTAS modifiers was associated with increased triage consistency.

Conclusions: eCTAS increased triage consistency for some high-volume presenting complaints, without indication of reducing consistency. Modifier use was associated with increased triage consistency, particularly for some non-specific complaints such as fever and general weakness.

Introduction

Triage is a fundamental process for the safe and efficient management of patients where health care demands exceed available emergency department (ED) resources. The Canadian Triage and Acuity Scale (CTAS) is the standard used in all Canadian and many international EDs to aid in safely determining the priority by which patients should be assessed.[1-7] The scale delineates 5 levels of acuity: level 1 (resuscitation), level 2 (emergent), level 3 (urgent), level 4 (less urgent) and level 5 (non-urgent).[8-11]

CTAS is similar to other triage algorithms including the Australasian Triage Scale (ATS)[12] and the Manchester Triage Scale (MTS)[13], which categorize patients based on perceived clinical urgency, but differs from other triage scales such as the Emergency Severity Index (ESI)[14], which also incorporates the anticipated number of resources that may be required. CTAS and the MTS also differ from the other triage algorithms by including standardized presenting complaint lists.[15-16]

Despite widespread adoption of CTAS guidelines, triage often relies on subjective judgment, and the process by which CTAS scores are assigned has been shown to vary significantly both within and between EDs.[4,5,17-19] In 2015, the government of Ontario agreed to fund the development and implementation of a standardized, electronic application to reduce triage variability across the province. eCTAS is a real-time electronic decision-support tool, designed to standardize the application of CTAS scores while respecting the nurse's autonomy in applying their clinical judgement.[20-21]

The application requires the user to select a presenting complaint from a standardized list of 169 complaints and then displays a CTAS-based template with complaint-specific modifiers (e.g., vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) to help ensure high risk time-sensitive conditions are not missed. This assists the user in assigning the appropriate CTAS score in real time.

We previously reported that eCTAS improves both interrater agreement and data accuracy without substantially increasing triage time.[21] In a prospective, observational study including 1491 real-time triage encounters in seven EDs, we found interrater agreement was higher after eCTAS implementation compared to pre-eCTAS (unweighted kappa 0.89 vs 0.63; quadratic-weighted kappa 0.93 vs. 0.79). The use of eCTAS significantly reduced the number of patients over-triaged (12.0% vs. 5.1%; Δ 6.9, 95% CI: 4.0, 9.7) and under-triaged (12.6% vs. 2.2%; Δ 10.4, 95% CI: 7.9, 13.2), and this was consistent across all participating sites. Median triage time was 312 seconds pre-eCTAS, compared to 347 seconds post-eCTAS (Δ 35 seconds, 95% CI: 29 to 40 seconds).

Given that CTAS is used to define ED case-mix groups for comparative and benchmarking processes, triage accuracy and consistency are important, but different, considerations; especially for regions that incorporate CTAS scores as part of their ED funding model.[22-25] Triage accuracy refers to how close the triage score is to the "truth" or reference standard, while triage consistency is a measure of variability and refers to how reproducible triage scores are within and between EDs. Despite widespread implementation (>90% of EDs) of this government mandated policy, it remains unknown if triage consistency has improved after the introduction of eCTAS across the province.

Goals of This Investigation:

The primary objective of this study was to assess differences in consistency of CTAS score distributions across institutions before and after e-CTAS implementation. Secondary objectives were to determine if hospital ED volume, triage process or use of eCTAS modifiers were associated with triage consistency.

Methods

Study setting and population:

This was a retrospective cohort study using population-based administrative databases from the province of Ontario from January 2016 to December 2018. All hospital EDs in Ontario that had implemented eCTAS for at least nine months were included. Following a 3-month stabilization period facilitating ED triage nurses familiarity with and consistent use of eCTAS, we compared data for 6 months post-eCTAS implementation to the same 6-month period the previous year (pre-implementation) to account for potential seasonal variation, patient volume and case-mix.

We included triage encounters of adult patients aged 17 years and older if they had one of the following 16 pre-specified high-volume, presenting complaints: altered level of consciousness; anxiety/situational crisis; chest pain (cardiac features); confusion; depression/suicidal/deliberate self-harm; extremity weakness/symptoms of cerebrovascular accident; fever; general weakness; head injury; hyperglycemia; palpitations; seizure; shortness of breath; substance misuse/intoxication; syncope; or vertigo. The 16 presenting complaints were *a priori* selected by a provincial steering committee to represent commonly encountered, high-volume conditions that

have a minimum allowable CTAS score (e.g., none of the included complaints should be assigned a CTAS score of 5). The provincial steering committee consisted of emergency physicians, triage nurses, researchers, and ED educators/managers, including the provincial master CTAS trainer who had 23 years of ED nursing and triage experience. A small committee first suggested the list, and it was approved by the provincial steering committee through debate and consensus.

Prior to the start of the study, CTAS had been the standard triage process for all participating EDs for at least 15 years. Prior to the implementation of eCTAS, all triage nurses completed a mandatory 2-hour training session consisting of didactic teaching and application practice using an online, interactive, simulated training environment with 10 standardized triage scenarios and real-time instruction on how to incorporate vital signs and relevant modifiers. For ongoing eCTAS training, all triage nurses have access to a training environment as soon as they receive their access credentials and can continue to access this environment for future training and updates. There is also a help guide that includes videos built into the eCTAS tool. The guide allows nurses to search any aspect of the tool and access a visual full training step by step guide to the section in question.

Data Sources

Data were obtained from province-wide health administrative databases through Ontario Health (Cancer Care Ontario), an agency of the provincial Government of Ontario responsible for improving healthcare services. Pre-eCTAS implementation data was obtained from the Canadian Institute of Health Information National Ambulatory Care Reporting System (CIHI-NACRS). CIHI-NACRS contains anonymized, abstracted data on all ED visits in Ontario. Post-eCTAS implementation data was obtained through the provincial eCTAS database. Ontario has universal

healthcare coverage for medically-necessary care, therefore, these databases contain the majority of healthcare utilization in the province. The study protocol was approved by the research ethics board at Mount Sinai Hospital in Toronto, Ontario, Canada.

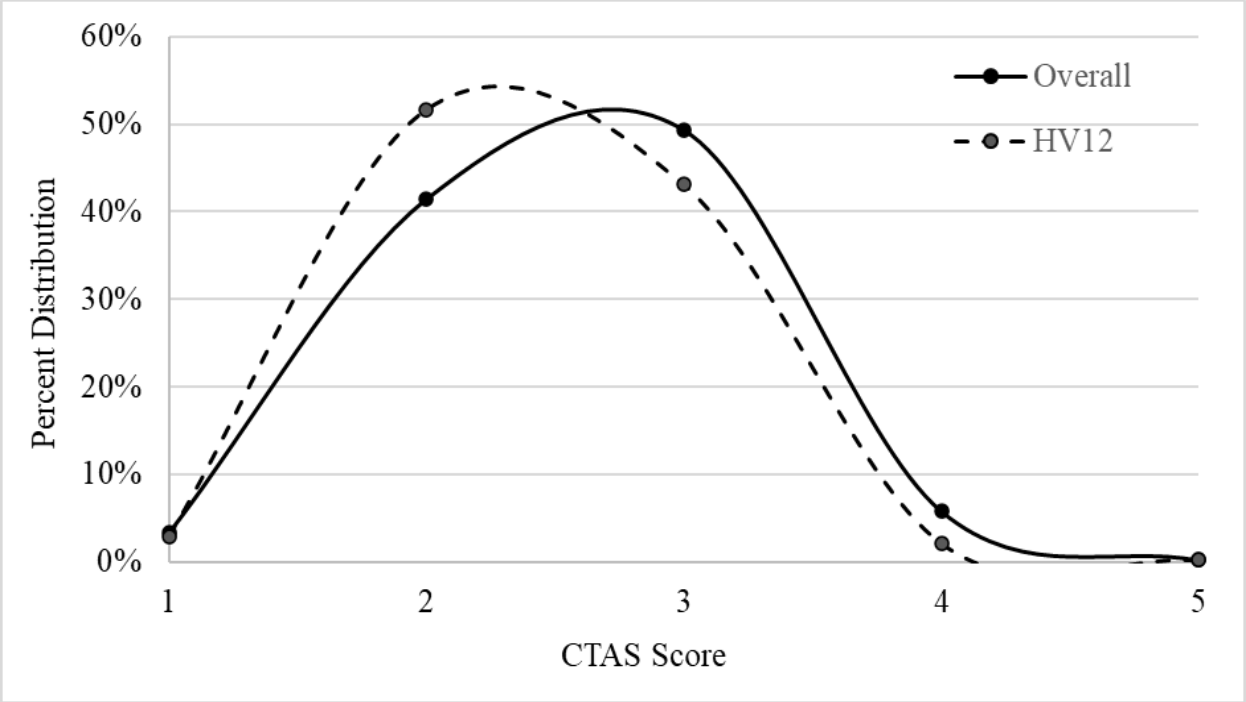
Data Analysis

The main exposure variable was the timing of the ED triage encounter, which was categorized as pre-eCTAS or post-eCTAS implementation. CTAS distributions were described using frequencies (%) and proportional differences were compared pre and post-eCTAS using chi-square statistics and presented as deltas (Δ = post-eCTAS % - pre-eCTAS %) with 95% confidence intervals (CIs).

To determine consistency, the overall CTAS distribution for all 35 included EDs was first calculated for each presenting complaint, pre and post-eCTAS implementation. Then the absolute difference in CTAS distribution for each presenting complaint was calculated for each hospital, pre and post-eCTAS, resulting in a pre-eCTAS change score and a post-eCTAS change score.

Figure 1 includes the data used to calculate the pre-eCTAS change score for the presenting complaint of "shortness of breath" for one of the included high-volume sites. The overall CTAS distribution for the presenting complaint of "shortness of breath" pre-eCTAS was 3.3% for CTAS 1, 41.4% for CTAS 2, 49.3% for CTAS 3, 5.8% for CTAS 4 and 0.2% for CTAS 5. The pre-eCTAS distribution for the same presenting complaint (shortness of breath) at the hospital was 2.9% for CTAS 1, 51.7% for CTAS 2, 43.1% for CTAS 3, 2.1% for CTAS 4 and 0.2% for CTAS 5 prior to eCTAS implementation.

Figure 1. Data used to calculate the pre-eCTAS change score for the presenting complaint of "shortness of breath" for one of the included high-volume sites.



	CTAS Distribution (%)				
	CTAS 1	**CTAS 2**	**CTAS 3**	**CTAS 4**	**CTAS 5**
OVERALL pre-eCTAS	3.3%	41.4%	49.3%	5.8%	0.2%
Individual ED (HV12) pre-eCTAS	2.9%	51.7%	43.1%	2.1%	0.2%
Absolute Delta	0.4	10.3	6.2	3.7	0

To calculate the pre-eCTAS change score for that hospital, we summed the absolute difference (0.4 + 10.3 + 6.2 + 3.7 + 0), resulting in a pre-eCTAS change score of 20.6%, which was rounded to 0.21 removing the percentage. The larger the ED change score, the more deviant the individual hospital CTAS distribution was from the overall CTAS distribution for all included sites. These change scores (n=1120) were calculated for all 35 EDs, for all 16 presenting complaints, pre and post-eCTAS implementation. A paired-samples t-test was used to compare the pre-eCTAS and

post-eCTAS change scores for each complaint, with each hospital acting as their own control. Mean pre-eCTAS and mean post-eCTAS changes scores are the average of the individual hospital change scores for each presenting complaint.

Consistency ratios for the change score were also calculated (pre-eCTAS change score/post-eCTAS change score) for each hospital by presenting complaint, with a value >1.0 indicating an increase in triage consistency with the overall CTAS distribution for all 35 included EDs. Mean consistency ratios are the average of the individual hospital consistency ratios for each presenting complaint. Analysis of variance (ANOVA) was used to compare consistency ratios by hospital ED volume (low volume <30,000 annual ED visits; medium volume 30,000 to 49,999 annual ED visits; high volume 50,000 to 84,999 annual ED visits and very high volume >85,000 annual ED visits). An independent samples t-test was used to compare consistency ratios by the ED triage process prior to the implementation of eCTAS (paper-based triage vs an electronic triage process).

We also captured the use of complaint-specific clinical modifiers (i.e., vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) for each triage encounter post-eCTAS implementation. Pearson product-moment correlation coefficients were used to estimate the strength and direction of association between the use of modifiers and post-eCTAS consistency change scores.[26] Data analyses were performed using Stata 16.0 (StataCorp LP, College Station, Texas).

Results

Thirty-five hospital EDs met the inclusion criteria of eCTAS use for at least nine months. There were eight (22.8%) low volume sites, eight (22.8%) medium volume sites, 13 (37.1%) high volume sites, and six (17.1%) very high volume sites. Prior to eCTAS, 15 (42.9%) EDs used a paper-based triage process, and 20 (57.1%) EDs used an electronic triage system. Of the 363,214 (183,231 pre-eCTAS, 179,983 post-eCTAS) triage encounters included, mean age (55.4 vs 55.6 years) and proportion of female patients (51.5% vs 51.8%) were similar pre and post-eCTAS implementation (Table 1).

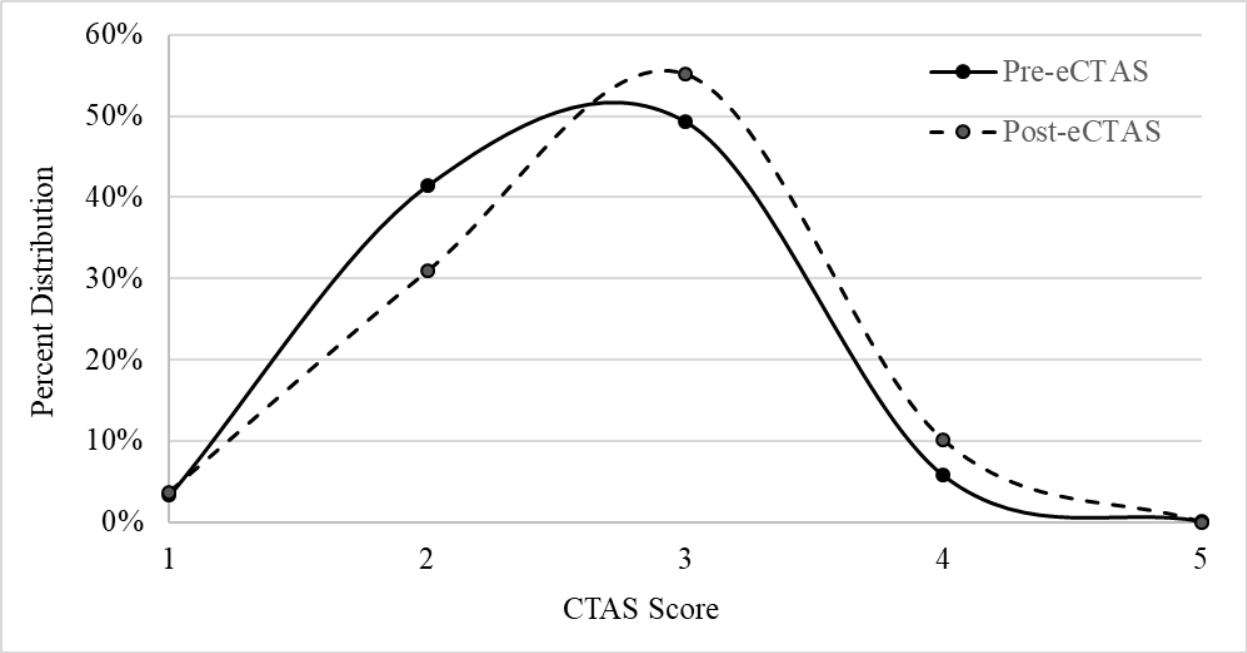
Table 1. Cohort descriptive statistics for 363,214 triage encounters from 35 hospital emergency departments for 16 included presenting complaints.

	Pre-eCTAS			Post-eCTAS		
Presenting Complaint	**n**	**Mean Age**	**Female**	**n**	**Mean Age**	**Female**
Altered Level of Consciousness	4,289	64.0	47.9%	3,913	64.9	48.8%
Anxiety/Situational Crisis	9,212	38.0	53.6%	8,578	38.3	54.2%
Chest Pain (Cardiac Features)	35,012	55.9	49.5%	36,744	56.4	49.8%
Confusion	3,361	73.3	49.4%	3,053	74.3	48.8%
Depression/Suicidal/Deliberate Self Harm	11,108	34.5	52.6%	11,467	34.3	51.5%
Extremity Weakness/Symptoms of CVA	5,356	68.8	50.7%	5,545	67.8	51.4%
Fever	10,642	48.1	51.5%	9,553	48.8	51.6%
General Weakness	17,409	68.5	54.0%	18,821	68.4	54.7%
Head Injury	13,282	51.8	51.3%	13,818	52.4	52.6%
Hyperglycemia	1,856	55.6	50.1%	1,907	54.7	48.7%
Palpitations/Irregular Heartbeat	8,708	57.4	55.3%	8,784	55.7	56.0%
Seizure	4,573	42.6	40.6%	3,889	43.3	41.1%
Shortness of Breath	30,855	62.0	53.2%	28,893	62.0	53.3%
Substance Misuse/Intoxication	6,393	38.8	33.6%	5,966	38.9	32.3%
Syncope/Pre-syncope	9,171	57.6	53.3%	9,294	58.1	53.9%
Vertigo	12,004	57.9	59.2%	9,758	58.1	60.6%
Grand Total	**183,231**	**55.4**	**51.5%**	**179,983**	**55.6**	**51.8%**

Where eCTAS = electronic Canadian Triage and Acuity Scale; CVA = cerebrovascular accident

Figure 2 shows the distribution of CTAS scores pre and post-eCTAS implementation for the presenting complaint of "shortness of breath". The distribution curves for the remaining 15 presenting complaints can be found in the supplementary appendix.

Figure 2. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Shortness of Breath."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=30,855)	1,016 (3.3%)	12,772 (41.4%)	15,216 (49.3%)	1,796 (5.8%)	51 (0.2%)
Post-eCTAS (n=28,893)	1,077 (3.7%)	8,937 (30.9%)	15,954 (55.2%)	2,925 (10.1%)	0 (0.0%)
Delta 95% CI	0.4 (0.1 to 0.7)	-10.5 (-11.2 to -9.7)	5.9 (5.1 to 6.7)	4.3 (3.9 to 4.7)	-0.2 (-0.2 to -0.1)

*4 records in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Table 2 presents pre and post-eCTAS consistency change scores for each of the 16 presenting complaints. Compared to pre-eCTAS, triage scores were more consistent with the overall CTAS distribution after the implementation of eCTAS for six (37.5%) presenting complaints: chest pain (cardiac features) ($p<0.001$), extremity weakness/symptoms of cerebrovascular accident ($p<0.001$), fever ($p<0.001$), shortness of breath ($p<0.001$), syncope ($p=0.02$), and hyperglycemia ($p=0.03$). Triage consistency was similar pre and post-eCTAS for altered level of consciousness, anxiety/situational crisis, confusion, depression/suicidal/deliberate self-harm, general weakness, head injury, palpitations, seizure, substance misuse/intoxication and vertigo.

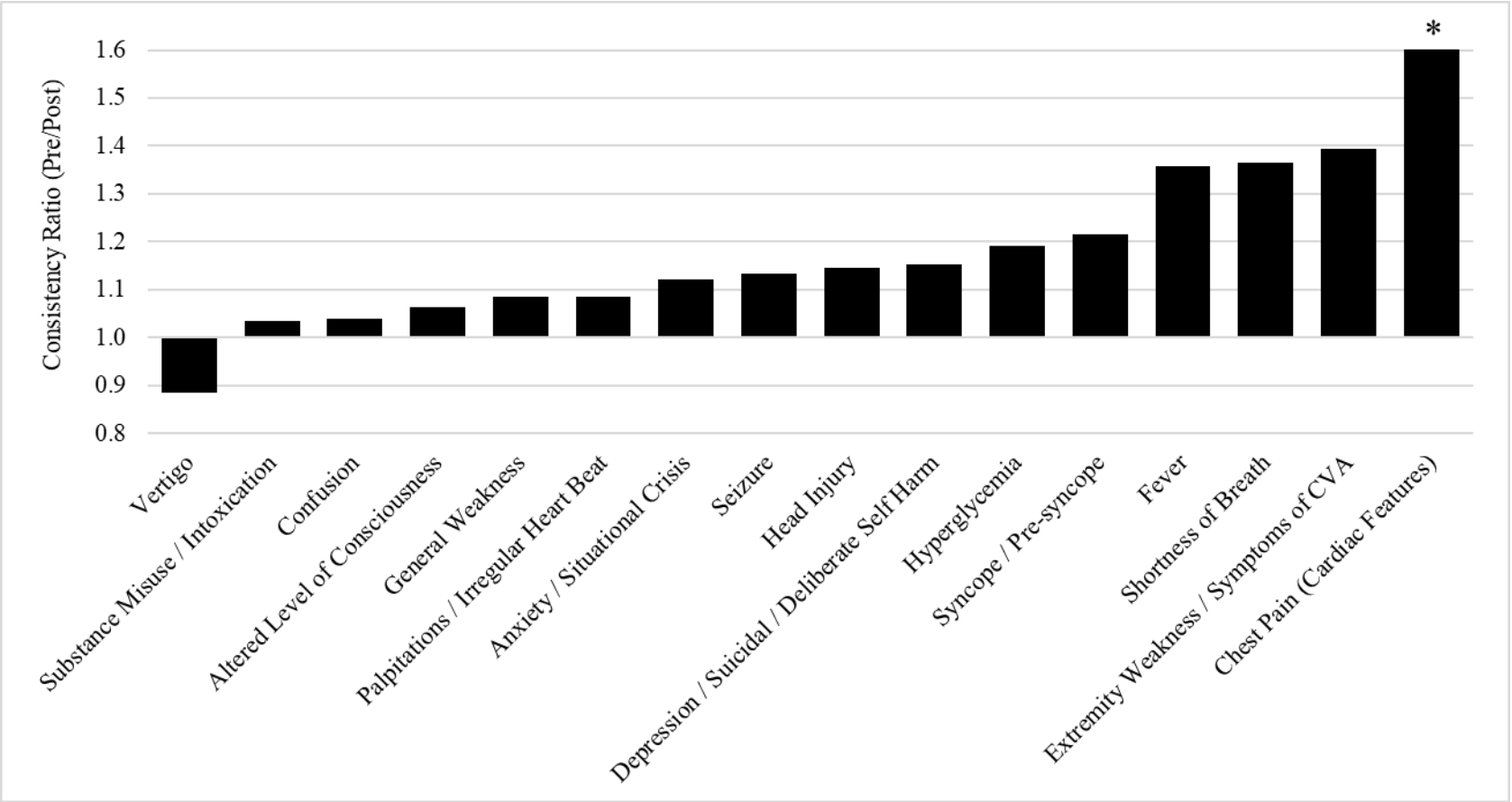
Figure 3 displays the average consistency ratios (pre-eCTAS/post-eCTAS change scores) for the 16 presenting complaints included in this study. All but one presenting complaint (vertigo) had consistency ratios greater than 1.0, indicating increased consistency with eCTAS. Consistency ratios for each presenting complaint broken down by each of the 35 included EDs can be viewed in the supplementary appendix. Consistency ratios were similar across hospital ED volumes (low, medium, high, very high volume) and previous triage processes (paper-based vs electronic) for most presenting complaints. Consistency ratios were higher for EDs transitioning from paper-based triage to eCTAS compared to EDs transitioning from an electronic triage system to eCTAS for the presenting complaints of chest pain (cardiac features) (93.7 vs 38.8; Δ 54.9; 95% CI: 8.9 to 101.1) and head injury (1.8 vs 1.1; Δ 0.7; 95% CI: 0.2 to 1.3).

Table 2. Pre and post-eCTAS consistency estimates for 16 presenting complaints.

Presenting Complaint	Pre-eCTAS Change Score	Post-eCTAS Change Score	Delta (95% CI)	t	p-value
Chest Pain (Cardiac Features)	0.27	0.01	0.26 (0.18 to 0.34)	6.55	<0.001
Extremity Weakness/Symptoms of CVA	0.41	0.29	0.12 (0.06 to 0.17)	4.28	<0.001
Fever	0.37	0.27	0.10 (0.06 to 0.14)	4.70	<0.001
Shortness of Breath	0.30	0.22	0.08 (0.05 to 0.11)	5.01	<0.001
Hyperglycemia	0.43	0.36	0.07 (0.01 to 0.13)	2.24	0.03
Syncope/Pre-syncope	0.36	0.30	0.06 (0.01 to 0.12)	2.47	0.02
Depression/Suicidal/Deliberate Self Harm	0.36	0.31	0.05 (-0.02 to 0.11)	1.49	0.15
Seizure	0.40	0.35	0.05 (-0.05 to 0.14)	0.98	0.33
Anxiety/Situational Crisis	0.28	0.25	0.03 (-0.03 to 0.09)	1.05	0.30
Head Injury	0.25	0.22	0.03 (-0.01 to 0.07)	1.72	0.10
General Weakness	0.26	0.24	0.02 (-0.02 to 0.06)	1.01	0.32
Palpitations/Irregular Heartbeat	0.32	0.30	0.02 (-0.04 to 0.09)	0.79	0.44
Altered Level of Consciousness	0.38	0.36	0.02 (-0.09 to 0.13)	0.42	0.68
Substance Misuse/Intoxication	0.34	0.33	0.01 (-0.04 to 0.07)	0.42	0.68
Confusion	0.32	0.31	0.01 (-0.10 to 0.12)	0.21	0.83
Vertigo	0.26	0.29	-0.03 (-0.09 to 0.02)	-1.22	0.23

Where eCTAS = electronic Canadian Triage and Acuity Scale; CVA = cerebrovascular accident

Figure 3. Average consistency ratios (pre-eCTAS/post-eCTAS) for 16 presenting complaints.



*Consistency ratio for Chest Pain (Cardiac Features) was 34.68.

Where eCTAS = electronic Canadian Triage and Acuity Scale; CVA = cerebrovascular accident

We found a statistically significant correlation between post-eCTAS consistency change scores and use of modifiers for 12 of the included presenting complaints, particularly for non-specific presenting complaints that are applicable to many different medical conditions (Table 3). The use of complaint-specific modifiers was highly correlated with increased consistency post-eCTAS for confusion, fever, general weakness, head injury, shortness of breath and vertigo; moderately correlated with increased consistency post-eCTAS for anxiety/situational crisis, depression/suicidal/deliberate self-harm, hyperglycemia, palpitations/irregular heartbeat and syncope/pre-syncope; and weakly correlated with increased consistency for altered level of consciousness.

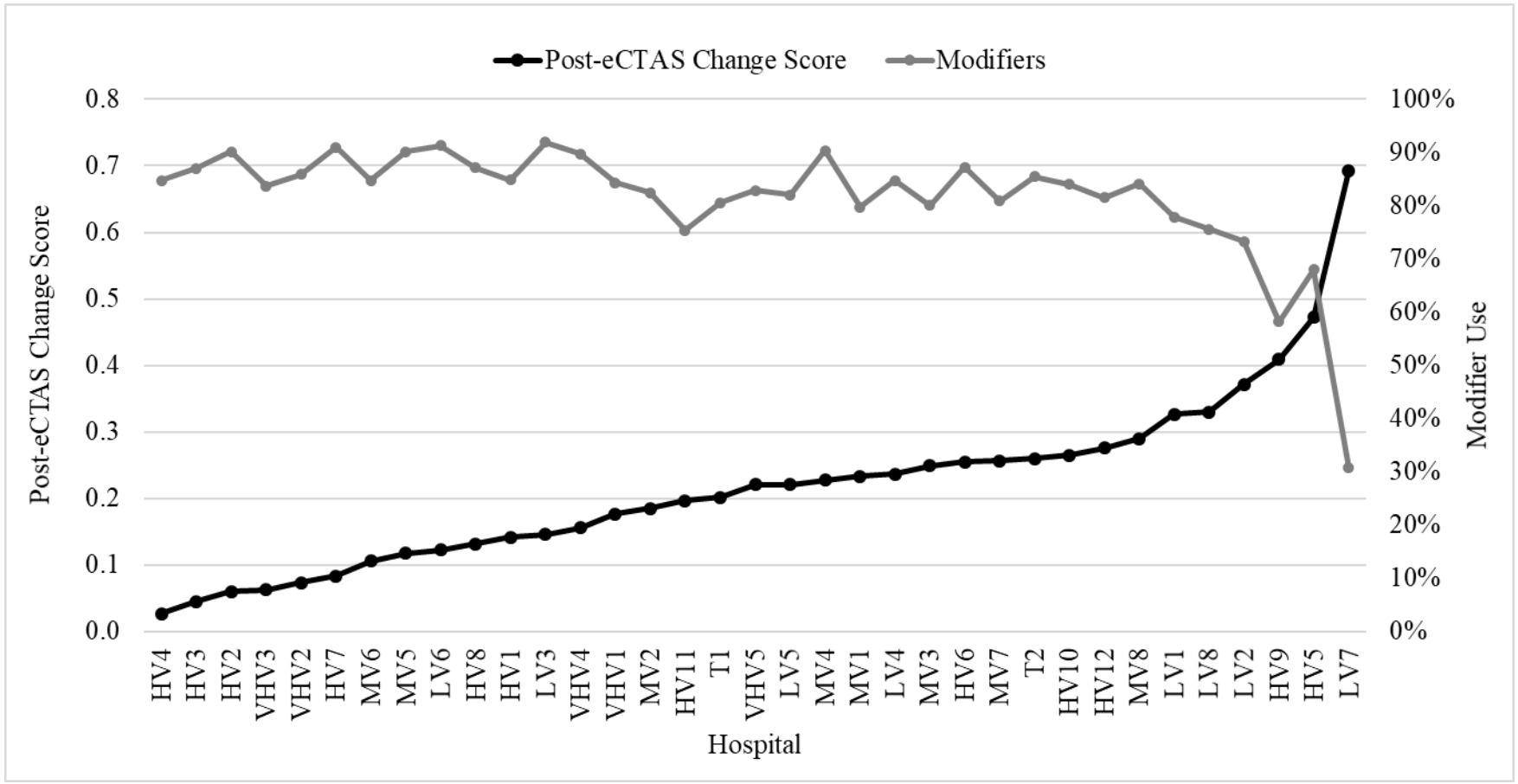
Figure 4 displays the post-eCTAS change scores and use of modifiers for "shortness of breath" for all 35 included EDs. Similar figures depicting the association between post-eCTAS changes scores and use of modifiers for the other presenting complaints can be viewed in the supplementary appendix. There was no discernable pattern for low modifier use, based on hospital volume, previous triage method (paper-based vs electronic) or presenting complaint.

Table 3. The association between post-eCTAS consistency change scores and use of modifiers for 16 presenting complaints.

Presenting Complaint	Post-eCTAS Change Score	Use of Modifiers	Pearson Correlation	p-value	Strength of Association
Shortness of Breath	0.22	84.13%	-0.85	<0.001	High
Fever	0.27	89.52%	-0.83	<0.001	High
Confusion	0.31	67.21%	-0.81	<0.001	High
Head Injury	0.22	77.77%	-0.75	<0.001	High
General Weakness	0.24	71.34%	-0.74	<0.001	High
Vertigo	0.29	61.12%	-0.73	<0.001	High
Anxiety/Situational Crisis	0.25	74.32%	-0.68	<0.001	Moderate
Hyperglycemia	0.36	80.07%	-0.66	<0.001	Moderate
Syncope/Pre-syncope	0.30	72.35%	-0.64	<0.001	Moderate
Palpitations/Irregular Heartbeat	0.30	80.09%	-0.60	<0.001	Moderate
Depression/Suicidal/Deliberate Self Harm	0.31	83.37%	-0.55	0.01	Moderate
Altered Level of Consciousness	0.36	78.20%	-0.39	0.02	Weak
Seizure	0.35	77.09%	-0.21	0.22	n/a
Extremity Weakness/Symptoms of CVA	0.29	61.26%	0.10	0.55	n/a
Chest Pain (Cardiac Features)	0.01	81.31%	-0.04	0.84	n/a
Substance Misuse/Intoxication	0.33	72.54%	-0.02	0.90	n/a

Where eCTAS = electronic Canadian Triage and Acuity Scale; CVA = cerebrovascular accident; n/a = not applicable

Figure 4. Post-eCTAS change score and use of modifiers by presenting complaint "Shortness of Breath" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Limitations

This study has several limitations. As of February 2020, eCTAS has been implemented in 114 (90%) EDs across the province. However, at the time of this study, only 35 EDs had implemented eCTAS for at least nine months (three-month stabilization period and at least six months of triage data using eCTAS) required to be included in this evaluation. It remains unknown if the overall consistency reported in this analysis is representative of all hospital EDs that have implemented eCTAS.

The 16 presenting complaints included in this study were selected by a provincial steering committee to represent commonly encountered, high-volume conditions that have a minimum allowable CTAS score (e.g., none of the included complaints should be assigned a CTAS score of 5). It is possible that triage consistency may be different for other presenting complaints. It is also possible that some of the increased consistency observed post-eCTAS implementation may be explained by the reduction in CTAS 5 use post-eCTAS. Another limitation is the uncertainty in the underlying assumption that the distribution of presenting complaint severities was similar across the 35 participating sites pre and post-eCTAS implementation.

We did not record the triage experience of the nurses included in this study, so we are unable to comment how this may have influenced triage consistency. We did not include paediatric (< 17 years) triage encounters, so it is possible that our results are not generalizable to that age demographic. Finally, there are no known benchmarks for what constitutes a clinically important improvement in triage consistency.

Discussion

This study evaluated the consistency of CTAS score distributions by presenting complaints six months pre and post-eCTAS implementation in EDs across Ontario. We found that a standardized, electronic approach to performing triage assessments increased consistency in CTAS scores for some high-volume presenting complaints, but had a mixed effect without indication of reducing consistency. We also found the use of complaint-specific modifiers was associated with increased triage consistency post-eCTAS, particularly for some non-specific presenting complaints such as shortness of breath, fever and general weakness.

Triage decisions are usually made under conditions of uncertainty. After a brief clinical assessment, often based on incomplete or ambiguous information, triage nurses must quickly assign a CTAS score based on the perceived acuity of the patient. Historically, triage decisions were generally subjective, influenced by triage experience, patient volume and current resource availability. Triage accuracy, consistency and timeliness may influence patient outcomes. Under-triage may contribute to delays in time-sensitive interventions and lead to potentially avoidable clinical deterioration and misdiagnosis. Over-triage, or labeling of patients with non-urgent presentations to high acuity designations, may lead to overutilization of scarce hospital resources and influence physician decisions, including hospital admission.[3,6,27-34]

Not all ED patients require a thorough and comprehensive triage. Patients who present with serious, life threatening illness or injury (e.g., cardiac arrest) can be quickly assessed and triaged based on their presenting complaint and general appearance. However, for the majority of patients presenting to the ED, more information is required before a CTAS score can be assigned. In these

cases, complaint-specific modifiers (e.g., vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) help determine the severity of the presenting complaint to assign the most appropriate CTAS score.[8-11] Based on the presenting complaint selected, eCTAS presents the relevant modifiers to the triage nurse and then electronically documents the modifier(s) selected and CTAS score.

We found the use of modifiers was associated with increased triage consistency post-eCTAS, particularly for non-specific complaints where patients may present with a wide spectrum of illness severity, such as shortness of breath, fever and general weakness. For example, a patient who presents to the ED with "shortness of breath" with normal vital signs who appears well may be appropriately triaged as CTAS 4, while another patient with the same presenting complaint (shortness of breath) who is asthmatic with moderate respiratory distress and a fever would be triaged as CTAS 2. The modifiers and computer-based prompts (e.g., standard deviation from the norm for age specific vital signs) in eCTAS help guide the clinical decision making of the triage nurse.

Previously, Lin and Worster suggested objective reliance on existing modifiers may greatly improve triage consistency and accuracy compared to subjective reliance on experience or intuition alone.[27] Similarly, Brown et al., tested interrater reliability and accuracy of CTAS scores for 20 mental health scenarios and found accuracy improved when triage nurses used complaint-specific modifiers.[34] In contrast, nurses that assigned the correct score less than 40% of the time were less likely to use complaint-specific modifiers or avoided their use altogether. The authors suggested the additional cues provided by the modifiers may help prompt triage nurses to consider

higher acuity or risk presentations, encouraging a more detailed assessment by the nurse to support clinical decision making.[34] Although we can only speculate why some nurses did not enter modifier data, it seems likely to be related to perceived process time, improper education or triage efficiency. Unknown system-level factors may also be a driving force behind these findings and future research should attempt to elucidate factors associated with use of modifiers.

Conclusions

In our study, a standardized, electronic approach to performing triage assessments increased consistency in CTAS scores for some high-volume presenting complaints, but had a mixed effect without indication of reducing consistency. Modifier use varied substantially between hospitals and presenting complaints. ED sites that were least consistent with the overall CTAS distribution had the lowest use of modifiers across all presenting complaints. Findings from this study may be useful to optimize the use of eCTAS in EDs that failed to show improvements in consistency and guide triage nurse education. Regular audit and feedback and a targeted educational curriculum clarifying the importance of modifier selection should improve triage consistency, particularly for some non-specific presenting complaints such as shortness of breath, fever and general weakness.

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Declaration of Interest: At the time of the study, SS, TA, JM, BF and NM were paid employees of Ontario Health (Cancer Care Ontario). HO is a paid advisor to the Ministry of Health of Ontario and in that capacity has provided leadership to the eCTAS project. SLM, CT, BB, LT, KG, AW, TA, MB and GG state no conflict of interest and have received no payment in preparation of this manuscript.

Author Contributions: SLM, BB, HO, NM conceived the study and designed the protocol. SLM, BB, SS, and GG supervised the conduct of the study. SLM, SS, TA, and BF managed the data, including quality control. SLM, CT, LT, AW, TA and GG provided advice on study design and data analysis. BB and NM chaired the data oversight committee. BB, HO, KG, JM, AW, TA, MB and GG provided clinical advice on study interpretation. SLM drafted the manuscript, and all authors contributed substantially to its revision. SLM takes responsibility for the paper as a whole.

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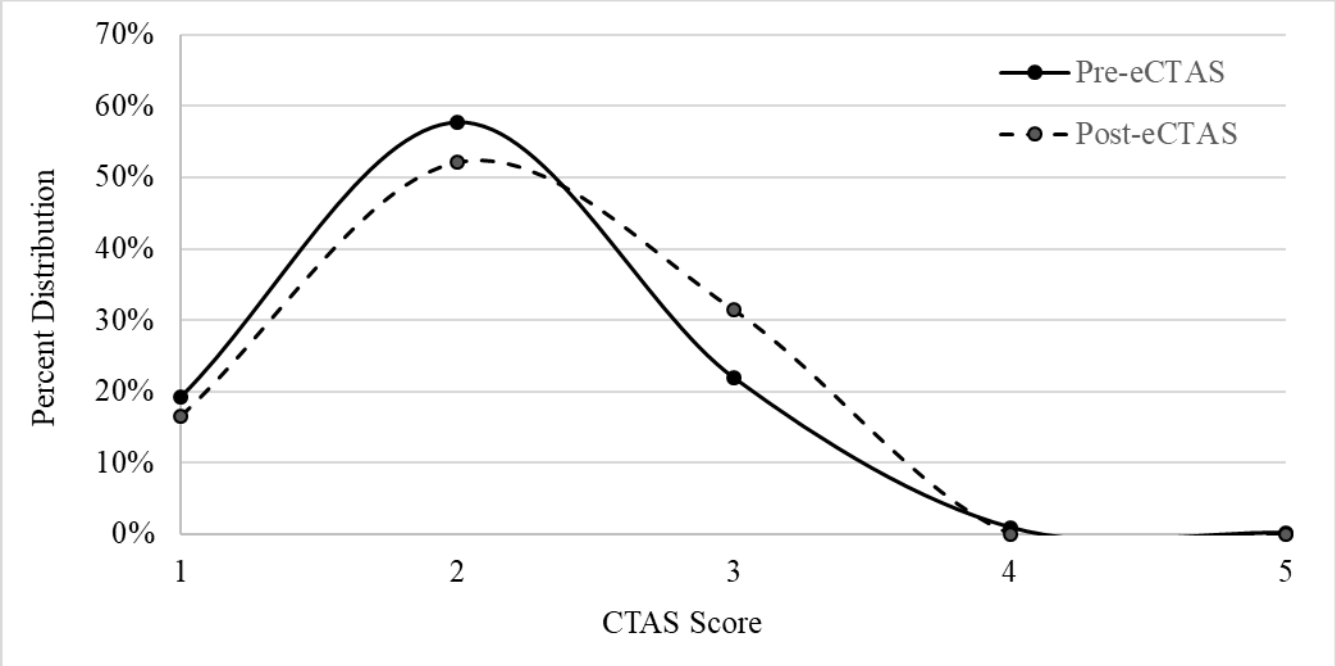
Appendix

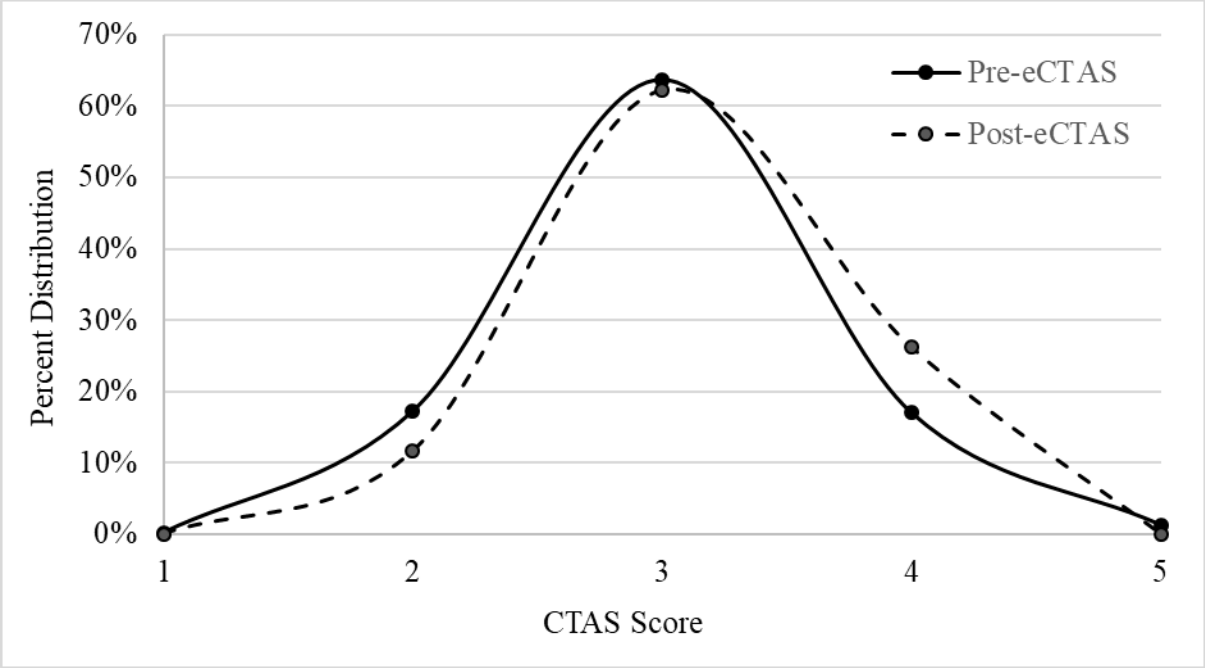
Supplementary Figure 1. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Altered Level of Consciousness."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=4,289)	827 (19.3%)	2,478 (57.8%)	939 (21.9%)	39 (0.9%)	6 (0.1%)
Post-eCTAS (n=3,913)	647 (16.5%)	2,038 (52.1%)	1,228 (31.4%)	0.0 (0.0%)	0.0 (0.0%)
Delta 95% CI	-2.8 (-4.4 to -1.1)	-5.7 (-7.8 to -3.5)	9.5 (7.6 to 11.4)	-0.9 (-0.6 to 1.2)	-0.1 (-0.3 to 0.0)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 2. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Anxiety/Situational Crisis."

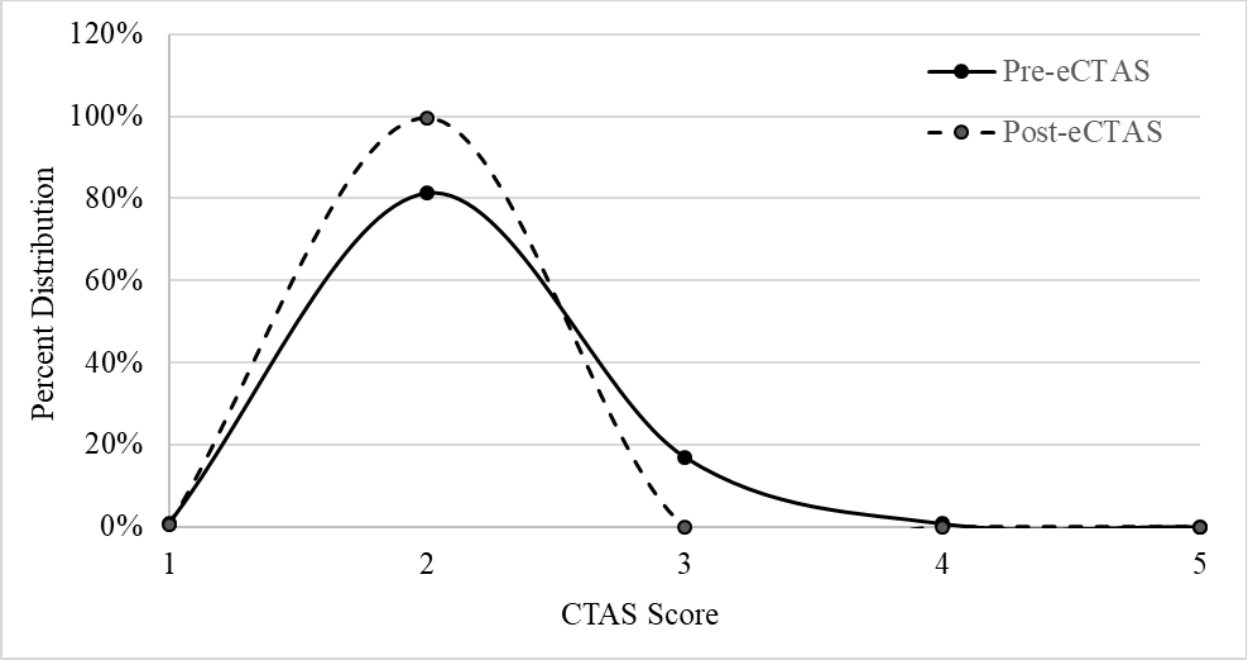


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=9,212)	20 (0.2%)	1,586 (17.2%)	5,867 (63.7%)	1,569 (17.0%)	120 (1.3%)
Post-eCTAS (n=8,578)	3 (0.0%)	997 (11.6%)	5,333 (62.2%)	2,245 (26.2%)	0.0 (0%)
Delta 95% CI	-0.2 (-0.3 to 0)	-5.6 (-6.6 to -4.6)	-1.5 (-2.9 to 0.1)	9.2 (7.9 to 10.3)	-1.3 (-1.5 to -1.1)

*50 records in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 3. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Chest Pain Cardiac Features."

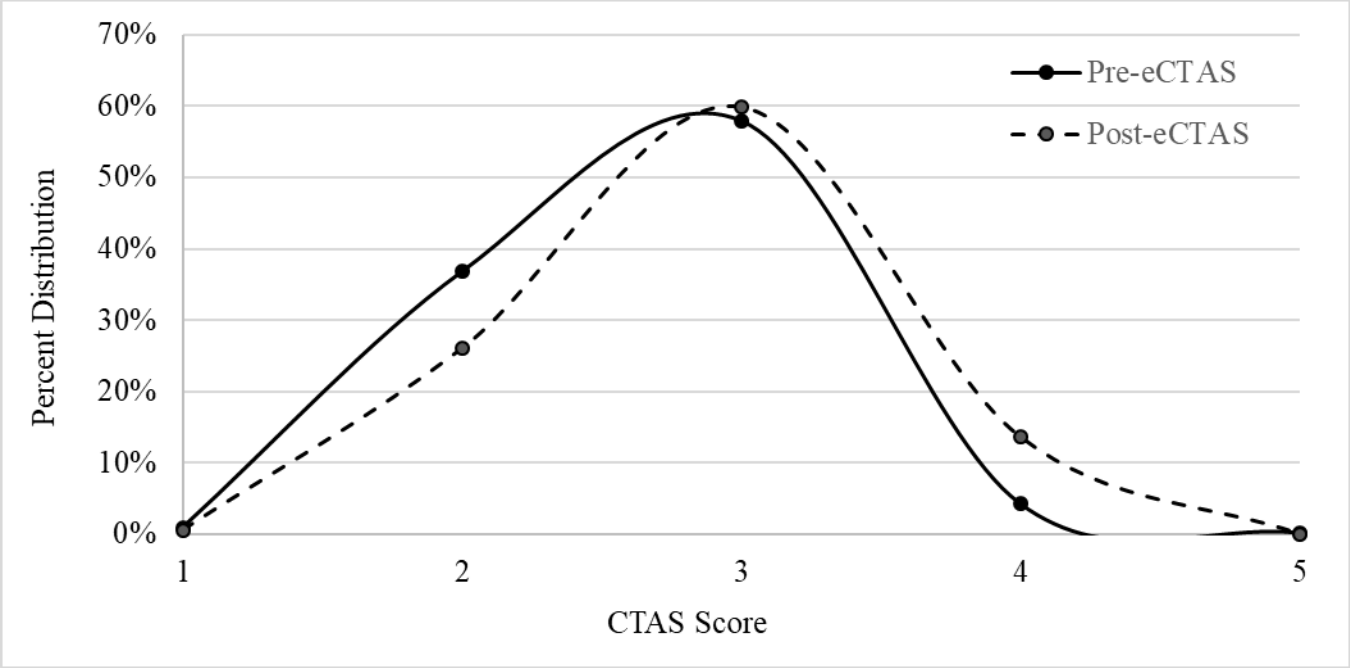


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=35,012)	286 (0.8%)	28,492 (81.4%)	5,964 (17.0%)	263 (0.7%)	6 (0.0%)
Post-eCTAS (n=36,744)	156 (0.4%)	36,580 (99.6%)	6 (0.0%)	2 (0.0%)	0 (0.0%)
Delta 95% CI	-0.4 (-0.5 to -0.3)	18.2 (17.8 to 18.6)	-17.0 (-17.4 to -16.6)	-0.7 (-0.8 to -0.6)	0.0 (0.0 to 0.0)

*1 record in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

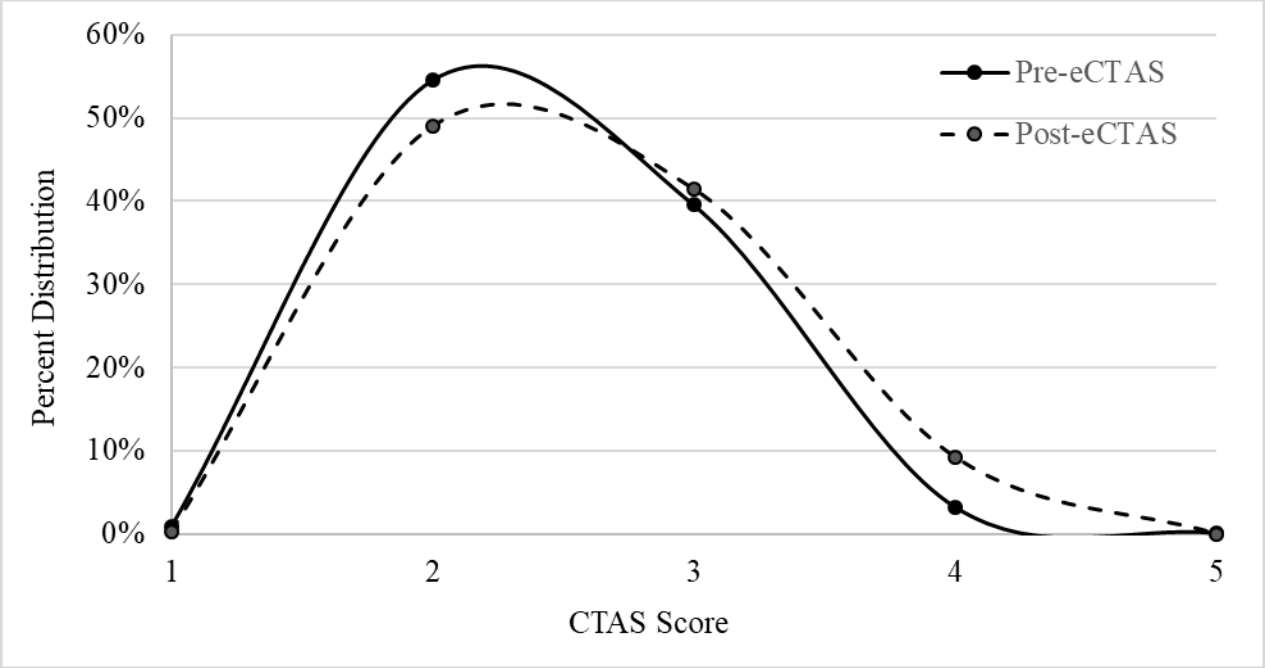
Supplementary Figure 4. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Confusion."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=3,361)	30 (0.9%)	1,236 (36.8%)	1,949 (58.0%)	142 (4.2%)	4 (0.1%)
Post-eCTAS (n=3,053)	17 (0.6%)	793 (26.0%)	1,827 (59.8%)	416 (13.6%)	0 (0.0%)
Delta 95% CI	-0.3 (-0.8 to 0.1)	-10.8 (-13.0 to -8.5)	1.8 (-0.6 to 4.3)	9.4 (8.0 to 10.8)	-0.1 (-0.2 to 0.0)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 5. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Depression/Suicidal/Deliberate Self Harm."

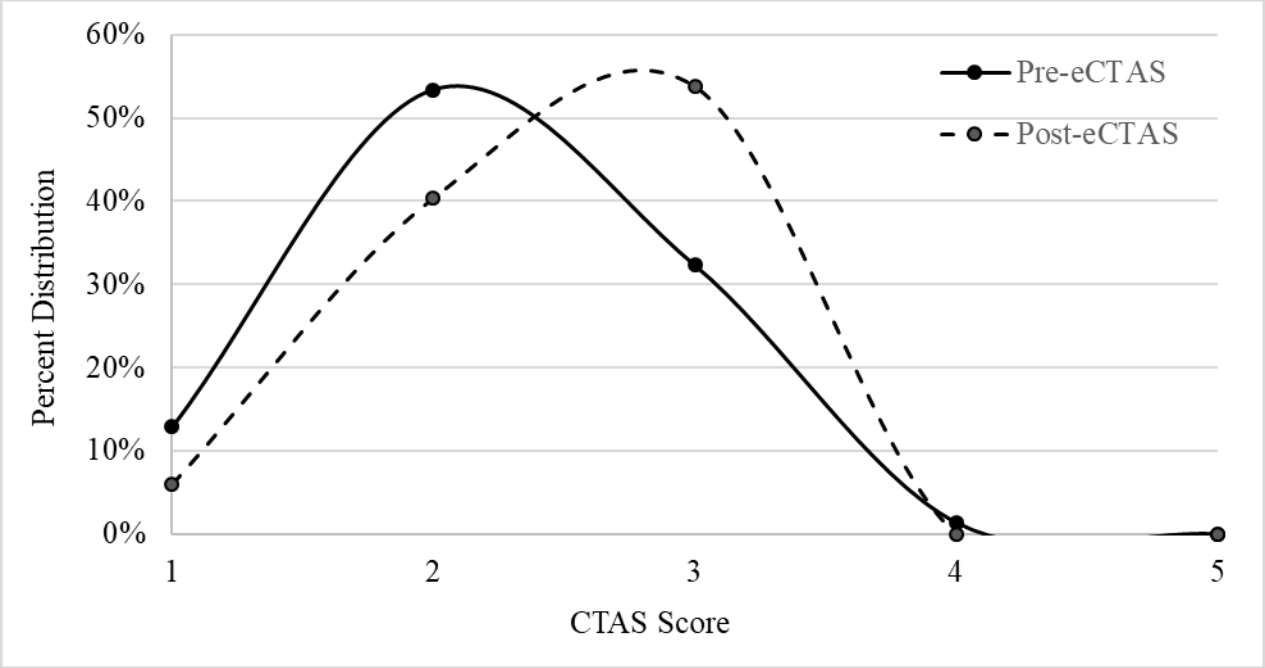


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=11,108)	100 (0.9%)	6,064 (54.6%)	4,394 (39.6%)	363 (3.3%)	18 (0.2%)
Post-eCTAS (n=11,467)	30 (0.3%)	5,625 (49.1%)	4,756 (41.5%)	1,056 (9.2%)	0 (0.0%)
Delta 95% CI	-0.6 (-0.8 to -0.4)	-5.5 (-6.8 to -4.2)	1.9 (-0.6 to 3.2)	5.9 (5.3 to 6.6)	-0.2 (-0.3 to -0.1)

*169 records in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 6. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Extremity Weakness/Symptoms of CVA."

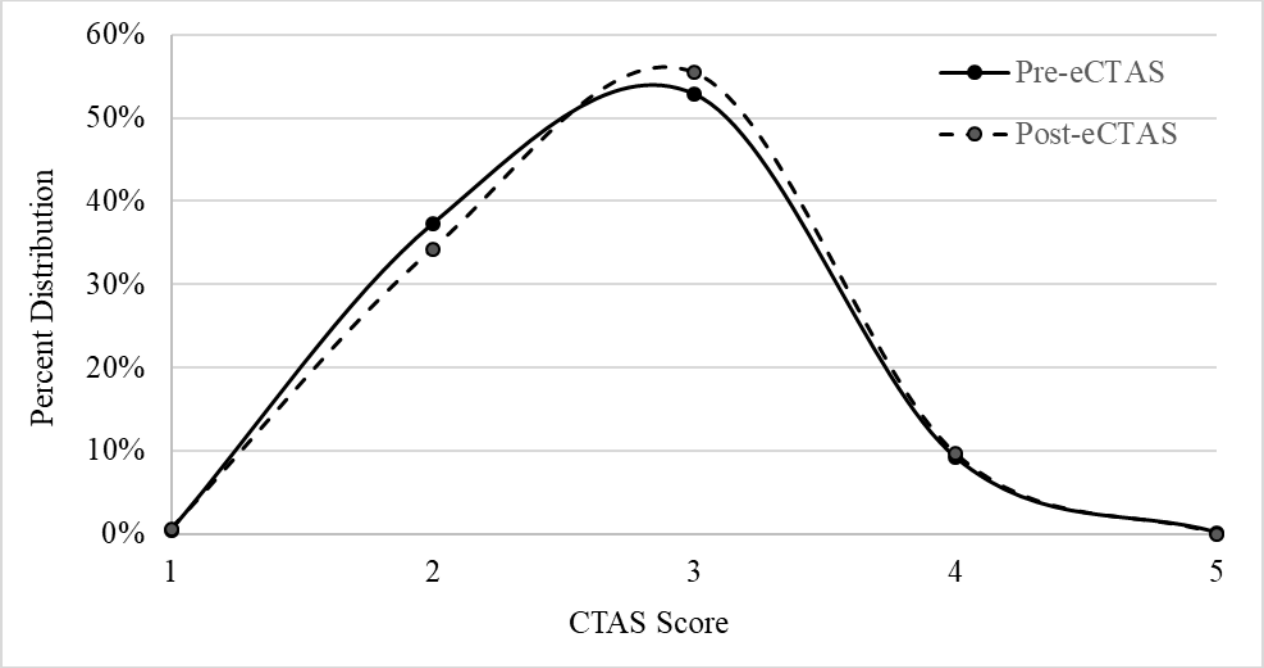


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=5,356)	689 (12.9%)	2,860 (53.4%)	1,730 (32.3%)	75 (1.4%)	1 (0.0%)
Post-eCTAS (n=5,545)	329 (5.9%)	2,235 (40.3%)	2,980 (53.7%)	1 (0.0%)	0 (0.0%)
Delta 95% CI	-7.0 (-8.0 to -6.0)	-13.1 (-14.9 to -11.2)	21.4 (19.6 to 23.2)	-1.4 (-1.7 to -1.1)	0.0 (0.0 to 0.0)

*1 record in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 7. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Fever."

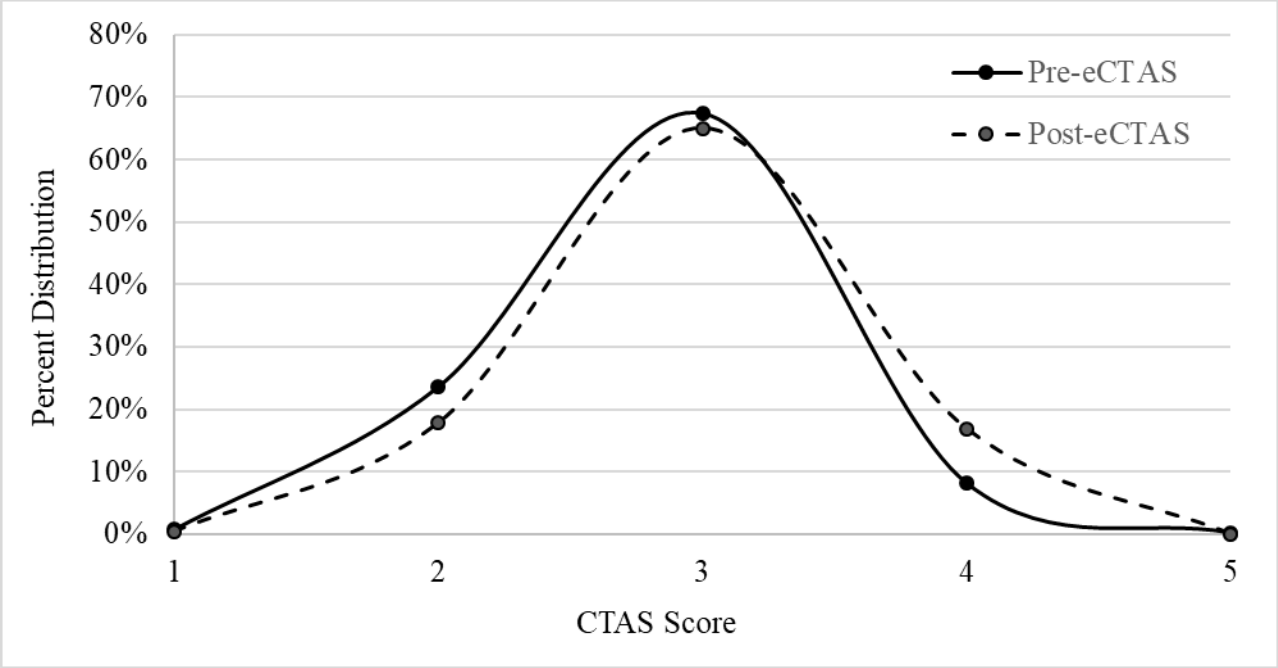


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=10,642)	51 (0.5%)	3,967 (37.3%)	5,626 (52.9%)	978 (9.2%)	18 (0.0%)
Post-eCTAS (n=9,553)	59 (0.6%)	3,275 (34.3%)	5,299 (55.5%)	920 (9.6%)	0 (0.0%)
Delta 95% CI	-0.1 (-0.3 to 0.0)	-3.0 (-4.3 to -1.7)	2.6 (1.2 to 4.0)	0.4 (-0.4 to 1.2)	0.0 (0.0 to 0.0)

*2 records in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 8. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "General Weakness."

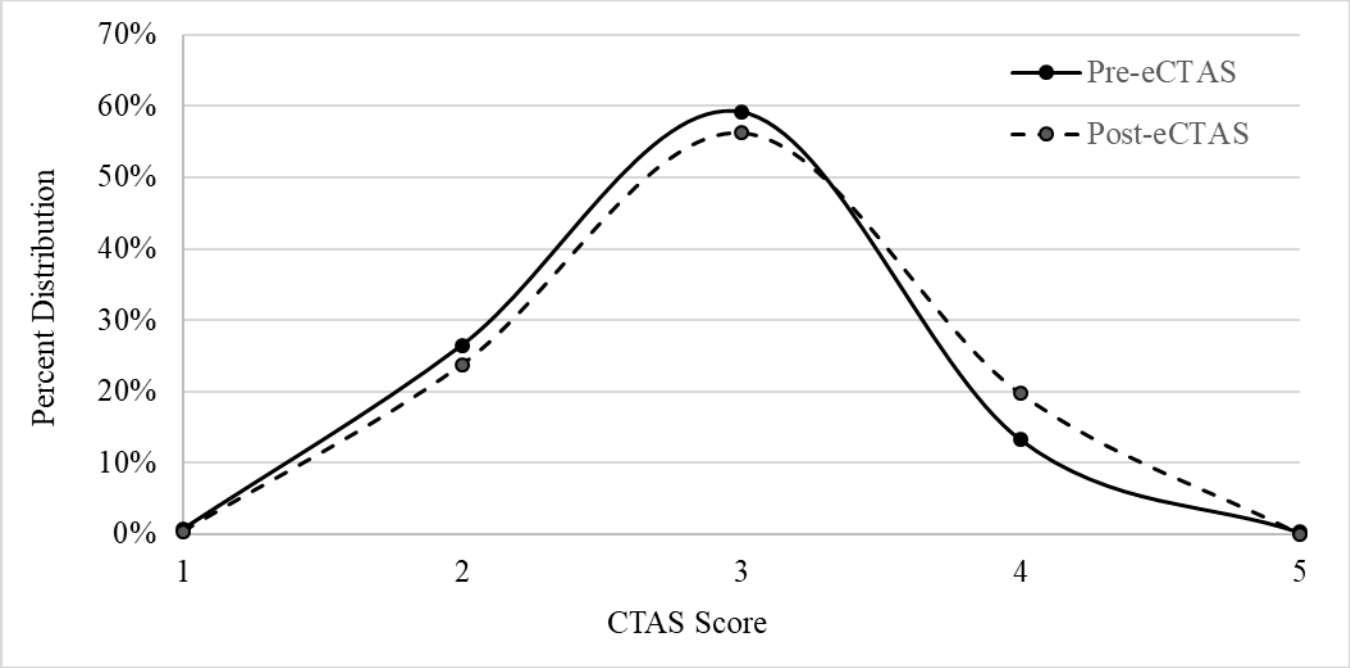


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=17,409)	121 (0.7%)	4,094 (23.5%)	11,724 (67.3%)	1,427 (8.2%)	41 (0.2%)
Post-eCTAS (n=18,821)	71 (0.4%)	3,340 (17.7%)	12,239 (65.0%)	3,171 (16.8%)	0 (0.0%)
Delta 95% CI	-0.3 (-0.5 to -0.2)	-5.8 (-6.6 to -4.9)	-2.3 (-3.3 to -1.3)	8.6 (7.9 to 9.3)	-0.2 (-0.3 to -0.1)

*2 records in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

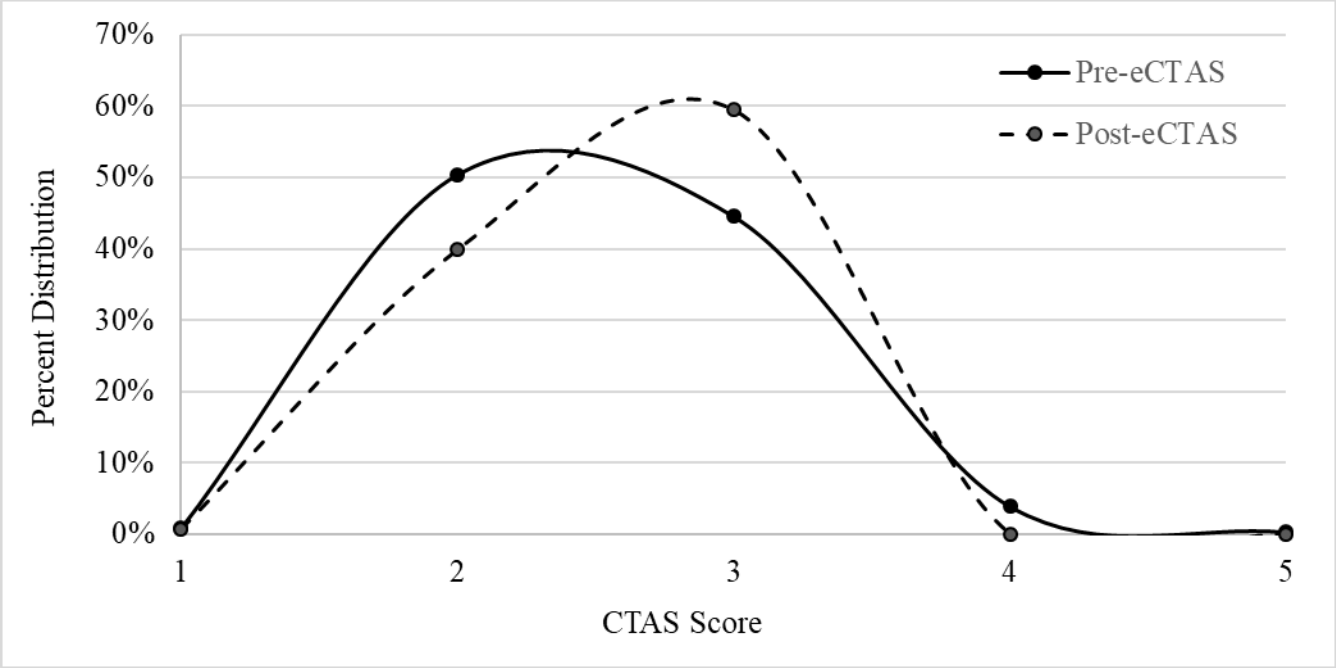
Supplementary Figure 9. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Head Injury."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=13,282)	99 (0.7%)	3,520 (26.5%)	7,861 (59.2%)	1,765 (13.3%)	37 (0.3%)
Post-eCTAS (n=13,818)	44 (0.3%)	3,280 (23.7%)	7,772 (56.2%)	2,722 (19.7%)	0 (0.0%)
Delta 95% CI	-0.4 (-0.6 to -0.2)	-2.8 (-3.8 to -1.7)	-3.0 (-4.1 to -1.8)	6.4 (5.5 to 7.3)	-0.3 (-0.4 to -0.2)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

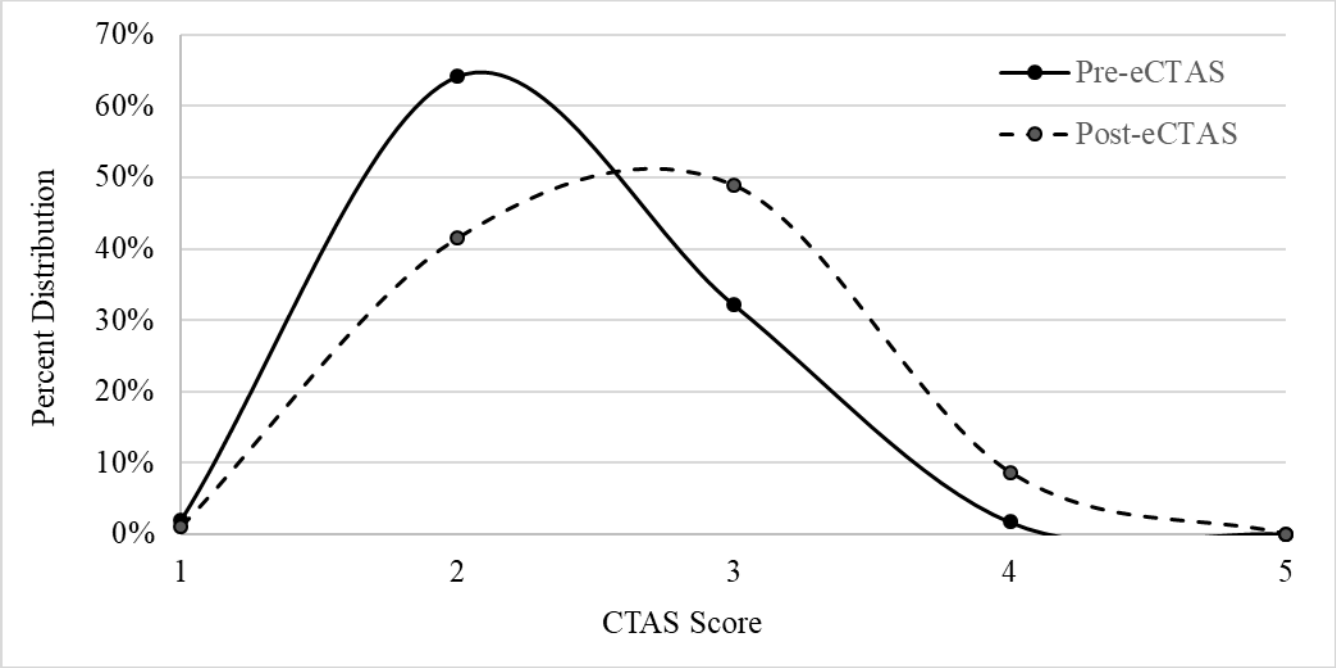
Supplementary Figure 10. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Hyperglycemia."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=1,856)	16 (0.9%)	936 (50.4%)	827 (44.6%)	72 (3.9%)	5 (0.3%)
Post-eCTAS (n=1,907)	13 (0.7%)	760 (39.8%)	1,134 (59.5%)	0 (0.0%)	0 (0.0%)
Delta 95% CI	-0.2 (-0.8 to 0.4)	-10.6 (-13.7 to -7.4)	14.9 (11.7 to 18.0)	-3.9 (-4.9 to -3.1)	-0.3 (-0.6 to 0.0)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

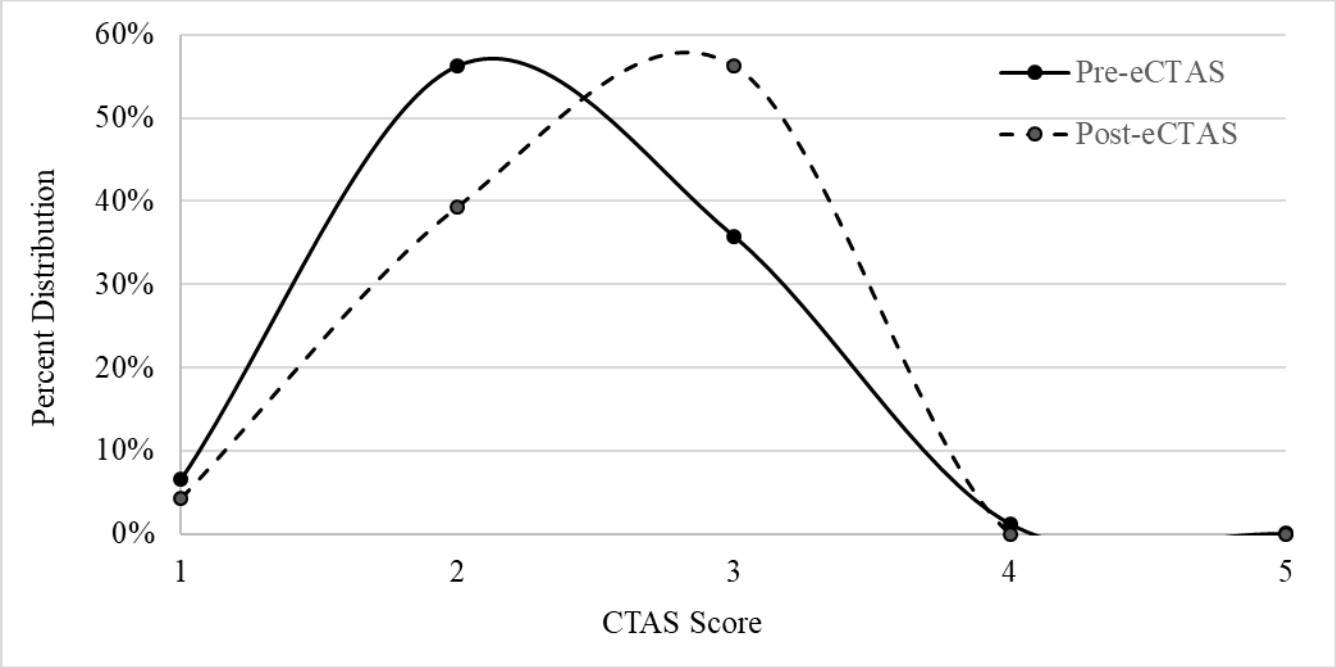
Supplementary Figure 11. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Palpitations/Irregular Heartbeat."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=8,708)	176 (2.0%)	5,586 (64.1%)	2,799 (32.1%)	146 (1.7%)	1 (0.0%)
Post-eCTAS (n=8,784)	86 (1.0%)	3,643 (41.5%)	4,296 (48.9%)	759 (8.6%)	0 (0.0%)
Delta 95% CI	-1.0 (-1.4 to -0.7)	-22.6 (-24.1 to -21.2)	16.8 (15.3 to 18.2)	6.9 (6.3 to 7.6)	0.0 (0.0 to 0.0)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

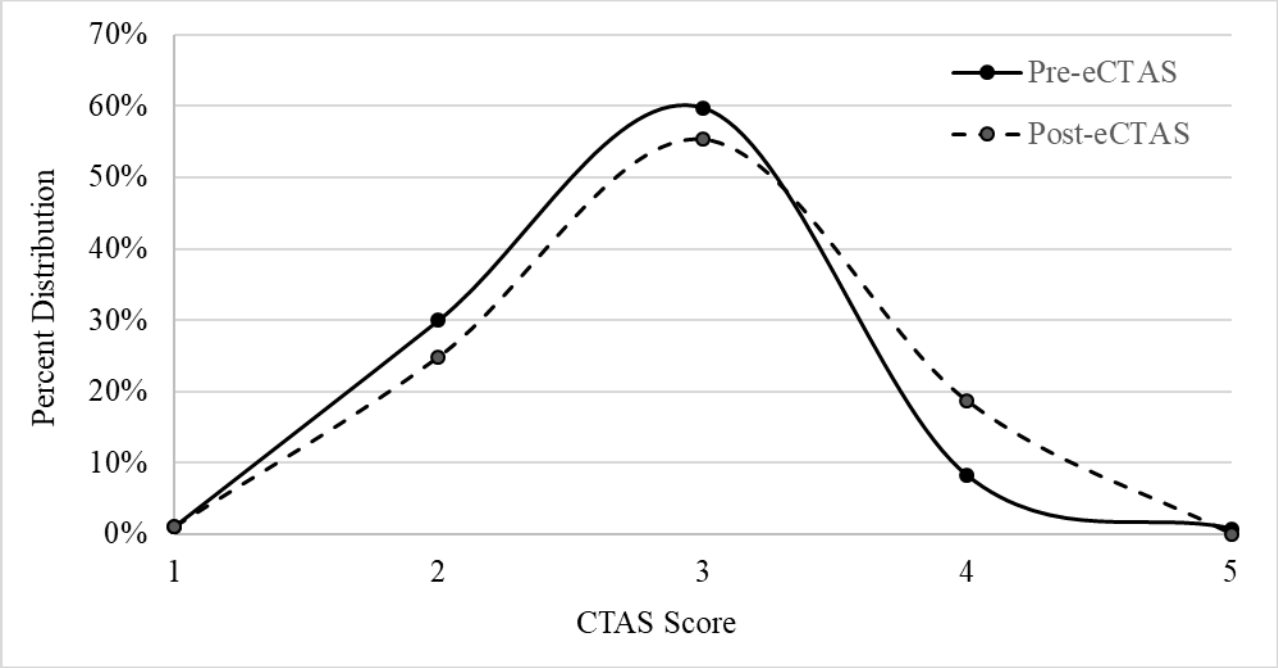
Supplementary Figure 12. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Seizure."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=4,573)	304 (6.6%)	2,572 (56.2%)	1,637 (35.8%)	58 (1.3%)	2 (0.0%)
Post-eCTAS (n=3,889)	167 (4.3%)	1,531 (39.4%)	2,191 (56.3%)	0 (0.0%)	0 (0.0%)
Delta 95% CI	-2.3 (-3.3 to -1.4)	-16.8 (-19.0 to -14.8)	20.5 (18.4 to 22.6)	-1.3 (-1.6 to -1.0)	0.0 (0.0 to 0.0)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 13. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Substance Misuse/Intoxication."

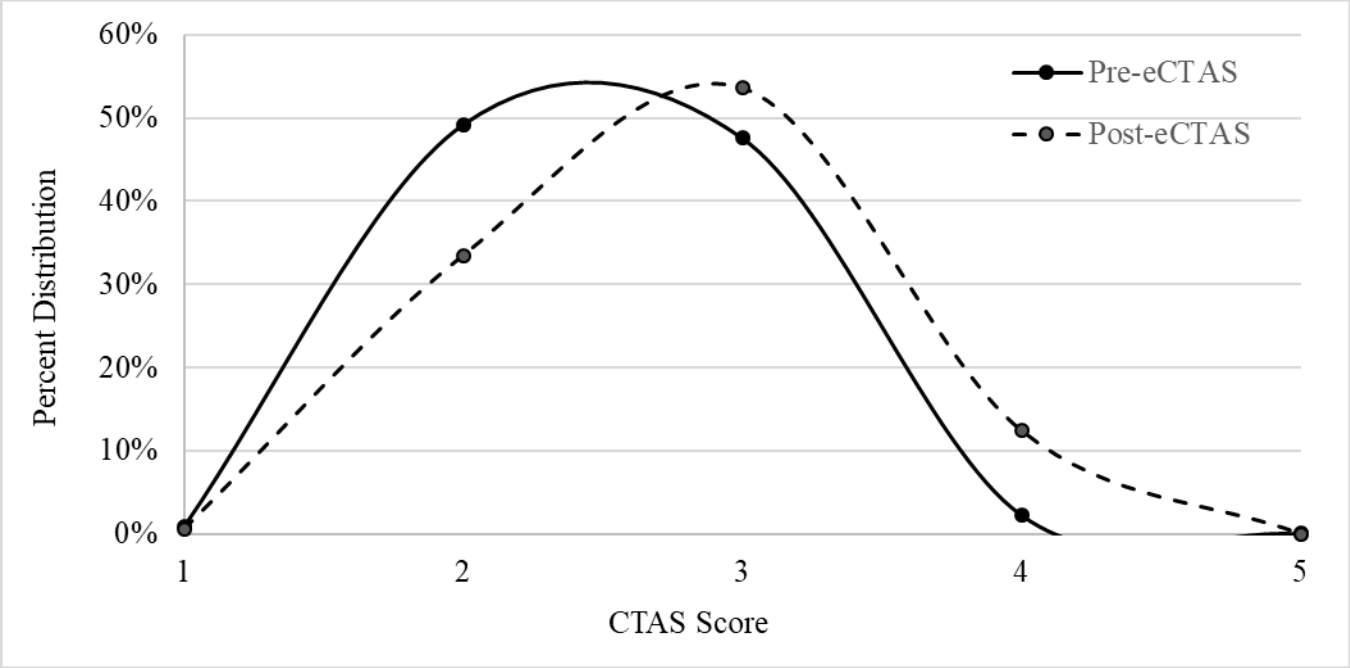


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=6,393)	63 (1.0%)	1,914 (29.9%)	3,820 (59.7%)	523 (8.2%)	49 (0.8%)
Post-eCTAS (n=5,966)	60 (1.0%)	1,484 (24.9%)	3,307 (55.4%)	1,115 (18.7%)	0 (0.0%)
Delta 95% CI	0.0 (-0.3 to 0.3)	-5.0 (-6.6 to -3.5)	-4.3 (-6.1 to -2.6)	10.5 (9.3 to 11.7)	-0.8 (-1.0 to -0.6)

*24 records in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

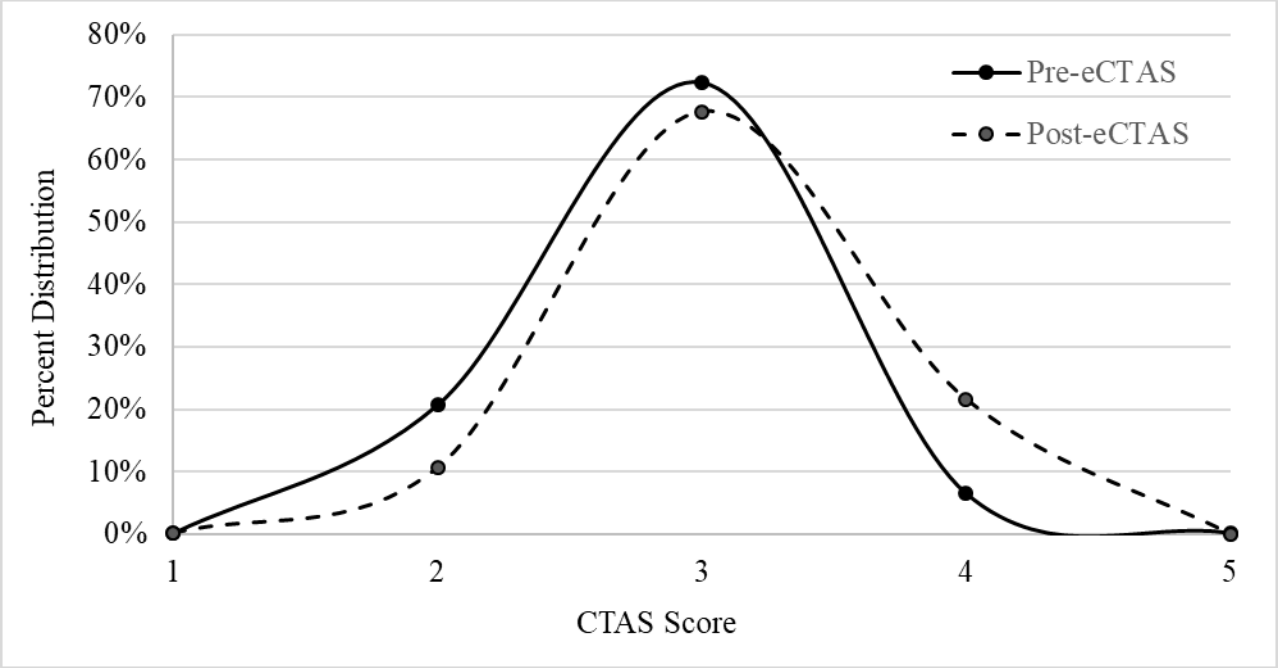
Supplementary Figure 14. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Syncope/Pre-syncope."



	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=9,171)	82 (0.9%)	4,509 (49.2%)	4,363 (47.6%)	212 (2.3%)	5 (0.0%)
Post-eCTAS (n=9,294)	52 (0.6%)	3,109 (33.4%)	4,979 (53.6%)	1,154 (12.4%)	0 (0.0%)
Delta 95% CI	-0.3 (-0.6 to -0.1)	-15.7 (-17.1 to -14.3)	6.0 (4.6 to 7.4)	10.1 (9.4 to 10.8)	0.0 (0.0 to 0.0)

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

Supplementary Figure 15. Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint "Vertigo."

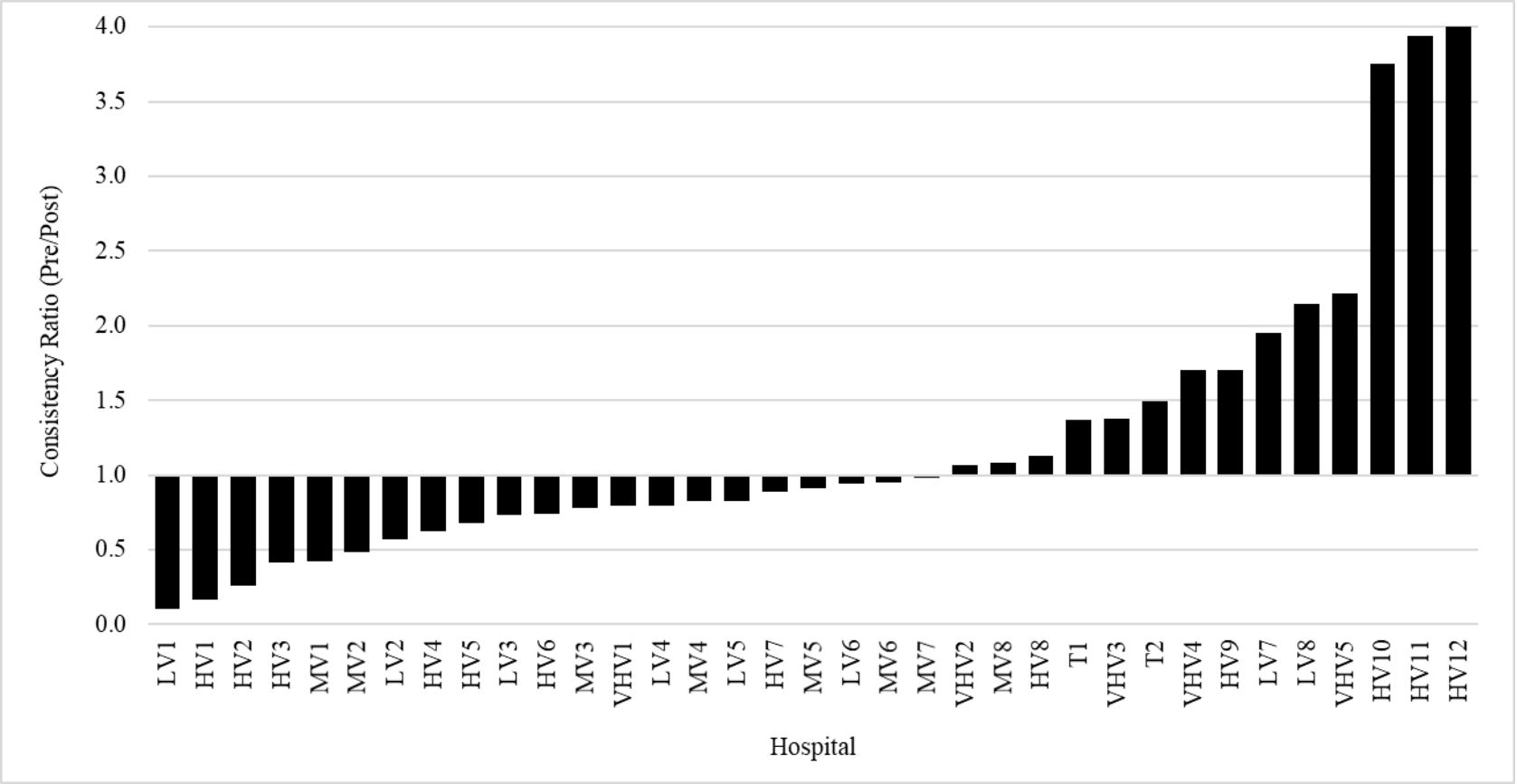


	CTAS Distribution (%)				
CTAS	**1**	**2**	**3**	**4**	**5**
Pre-eCTAS (n=12,004)	16 (0.1%)	2,486 (20.7%)	8,694 (72.4%)	786 (6.5%)	21 (0.2%)
Post-eCTAS (n=9,758)	13 (0.1%)	1,038 (10.6%)	6,601 (67.6%)	2,106 (21.6%)	0 (0.0%)
Delta 95% CI	0.0 (0.0 to 0.0)	-10.1 (-11.0 to -9.1)	-4.8 (-6.0 to -3.6)	15.1 (14.1 to 16.0)	-0.2 (-0.2 to -0.1)

*1 record in the pre-eCTAS cohort did not have a triage score.

Where: CTAS = Canadian Triage and Acuity Scale; CI = confidence interval.

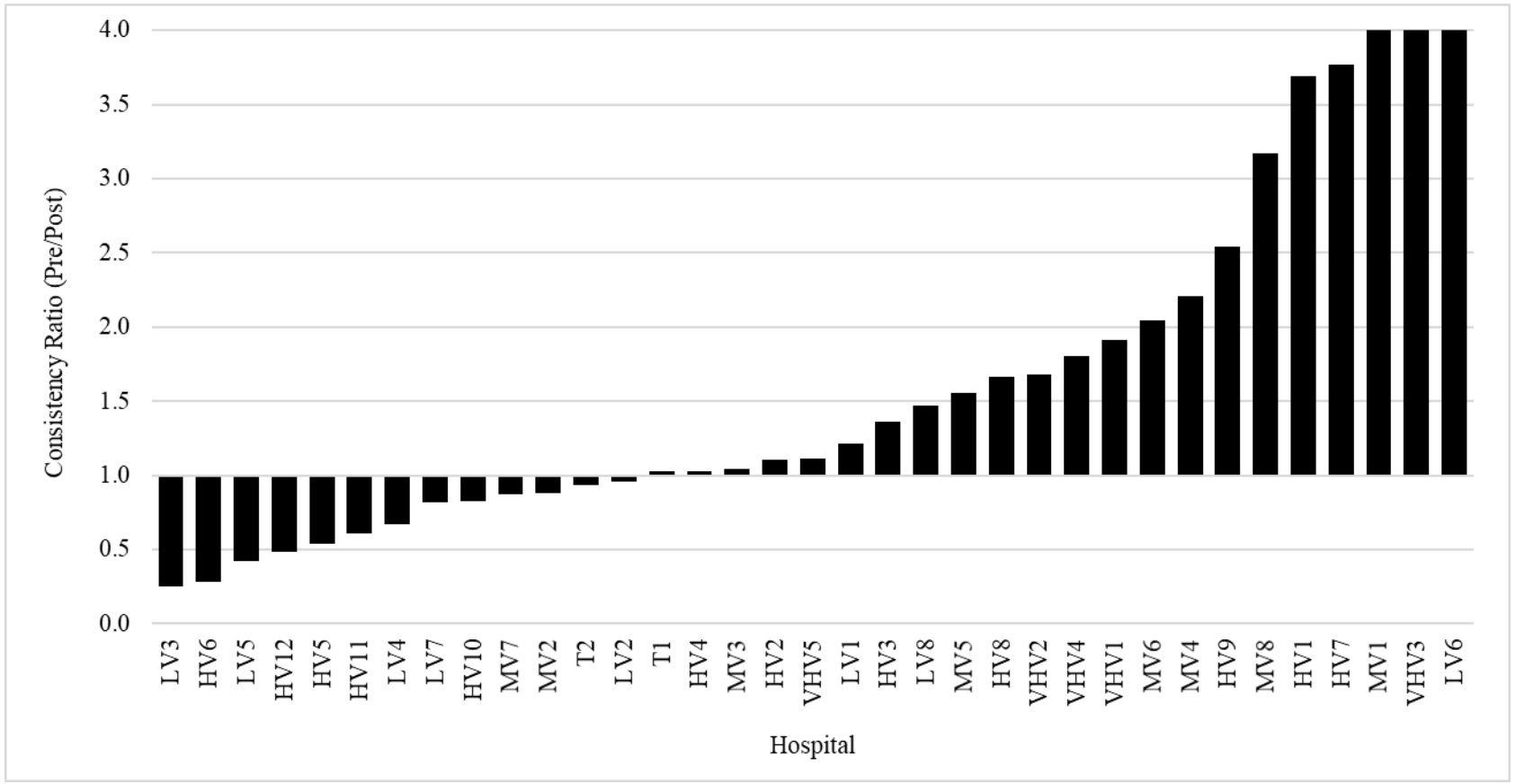
Supplementary Figure 16. Consistency ratios by presenting complaint "Altered Level of Consciousness" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

*Consistency ratio for HV12 = 7.42.

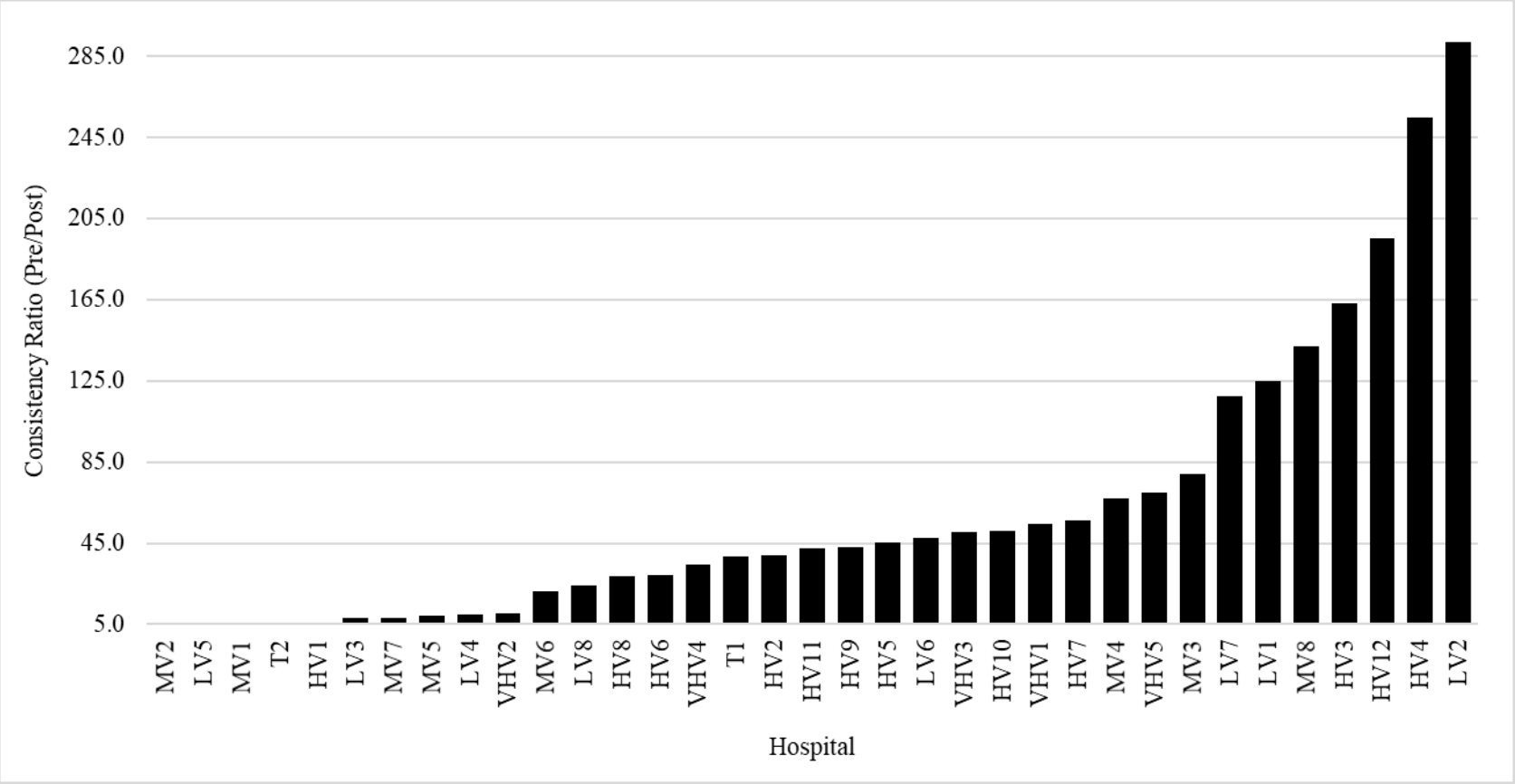
Supplementary Figure 17. Consistency ratios by presenting complaint "Anxiety / Situational Crisis" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

*Consistency ratio for VHV3 = 7.51 and LV6 = 15.73.

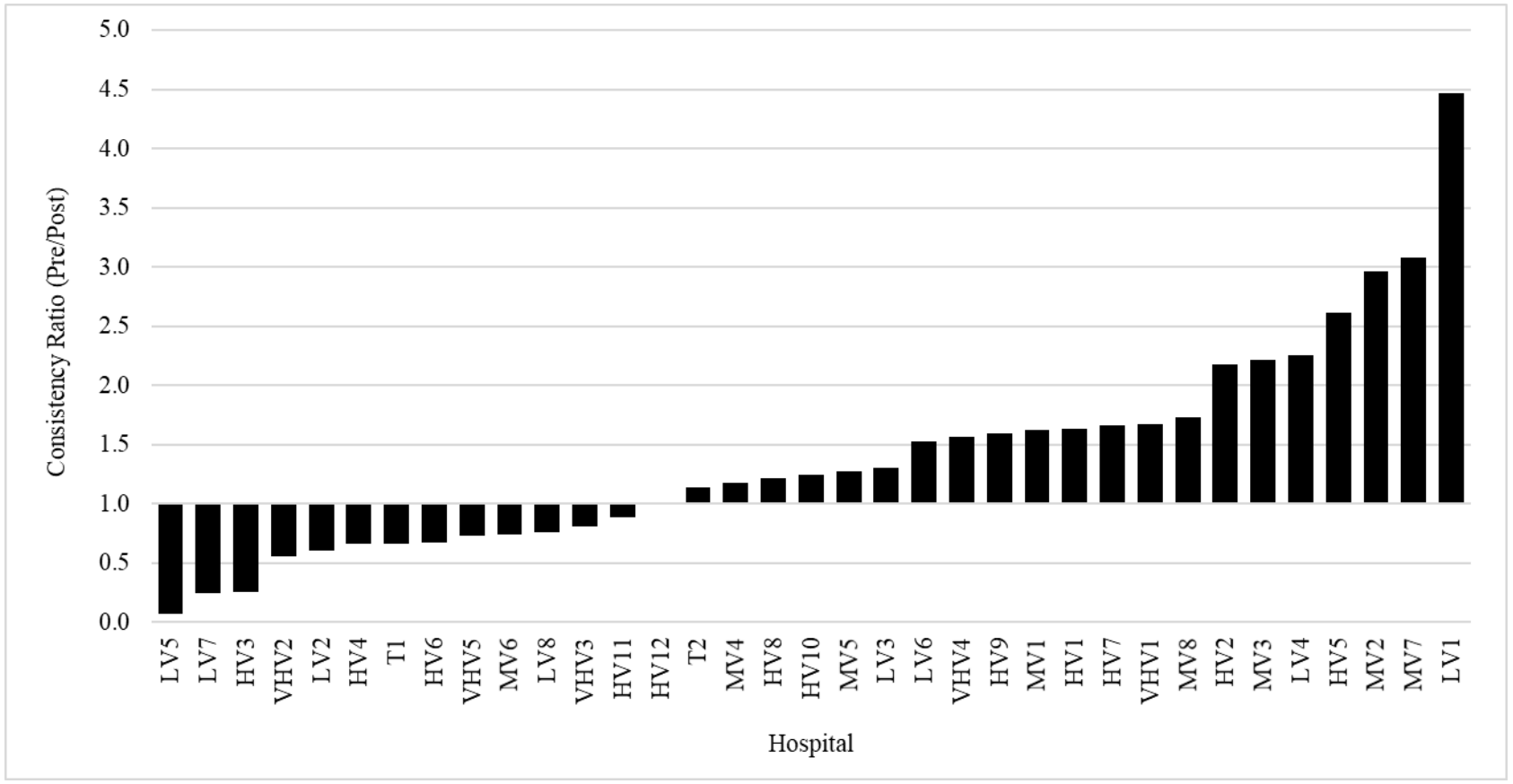
Supplementary Figure 18. Consistency ratios by presenting complaint "Chest Pain (Cardiac Features)" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

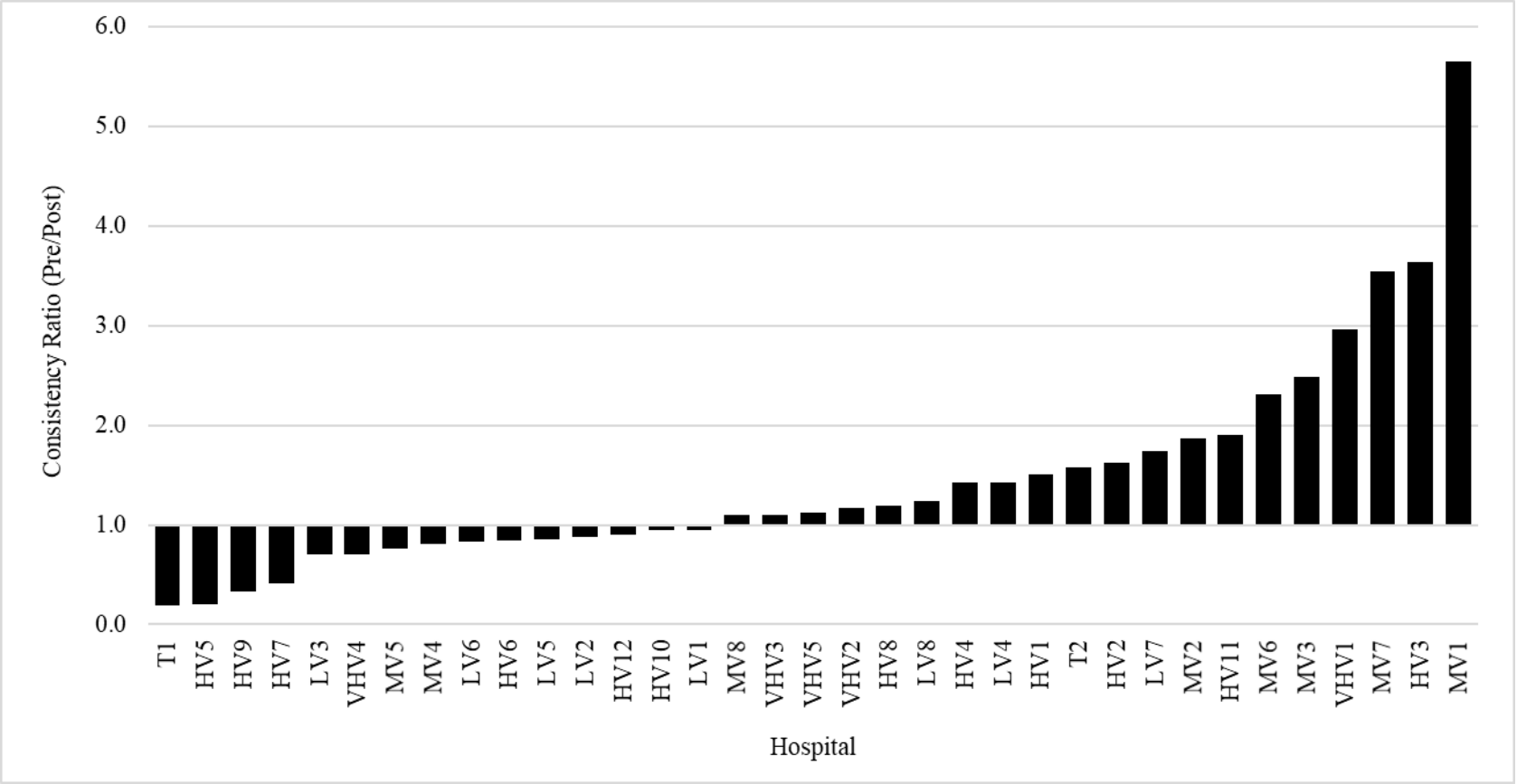
*Consistency ratio for MV2 = 2.23; LV5 = 3.40; MV1 = 5.50; T2 = 5.85; HV1 = 5.96; LV2 = 292.09.

Supplementary Figure 19. Consistency ratios by presenting complaint "Confusion" for 35 hospitals across Ontario.



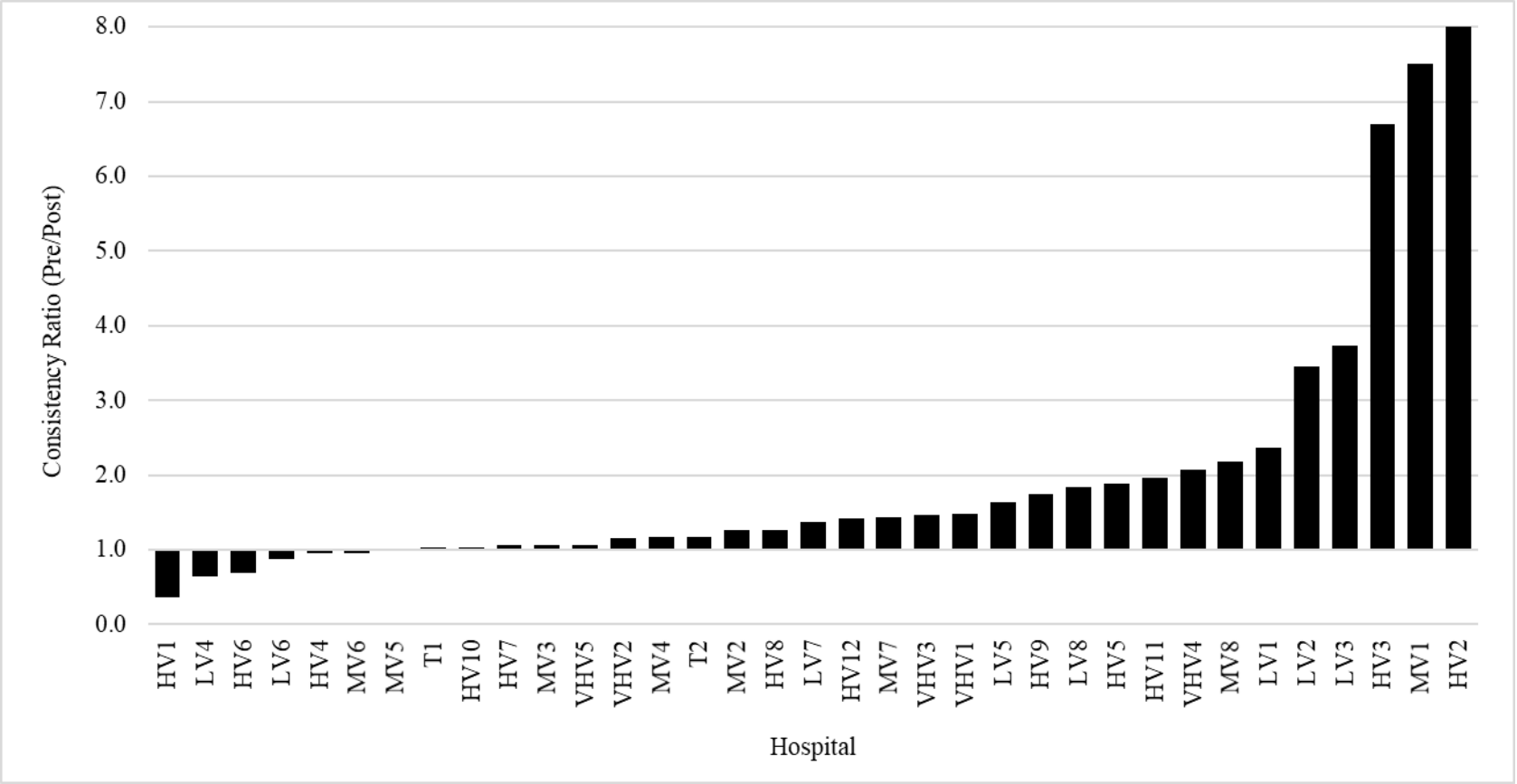
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 20. Consistency ratios by presenting complaint "Depression / Suicidal / Deliberate Self Harm" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

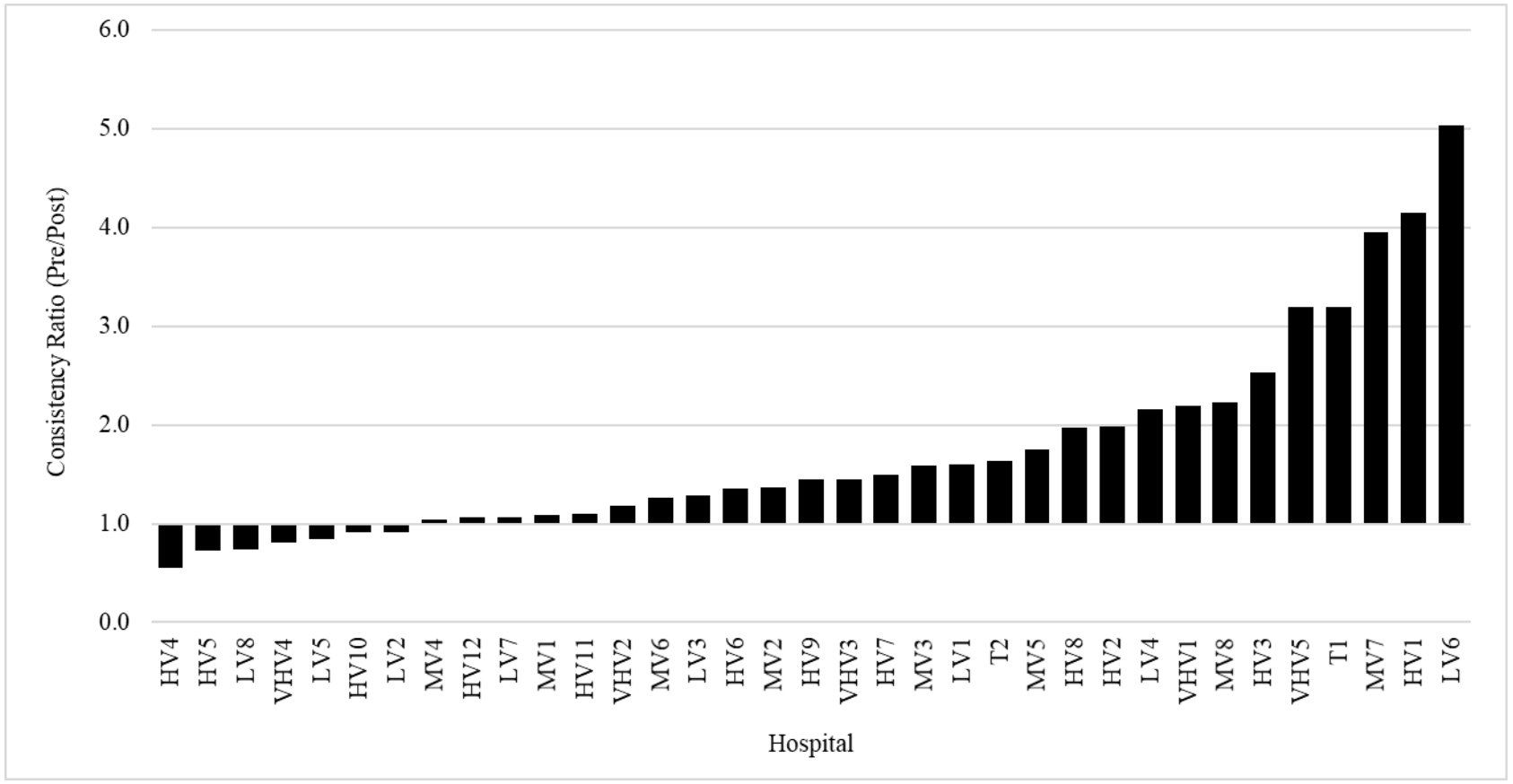
Supplementary Figure 21. Consistency ratios by presenting complaint "Extremity Weakness / Symptoms of CVA" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

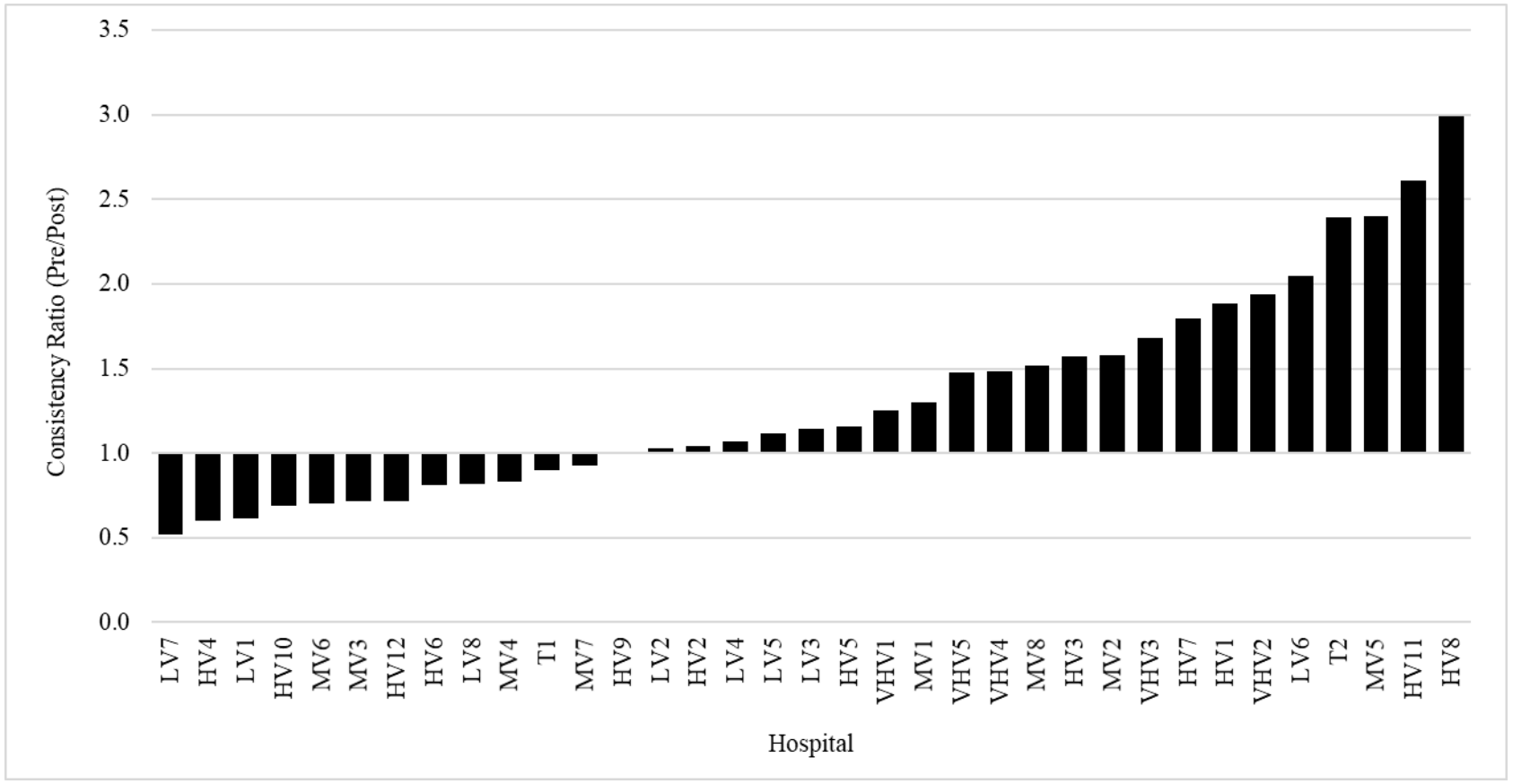
*Consistency ratio for HV2 = 10.86.

Supplementary Figure 22. Consistency ratios by presenting complaint "Fever" for 35 hospitals across Ontario.



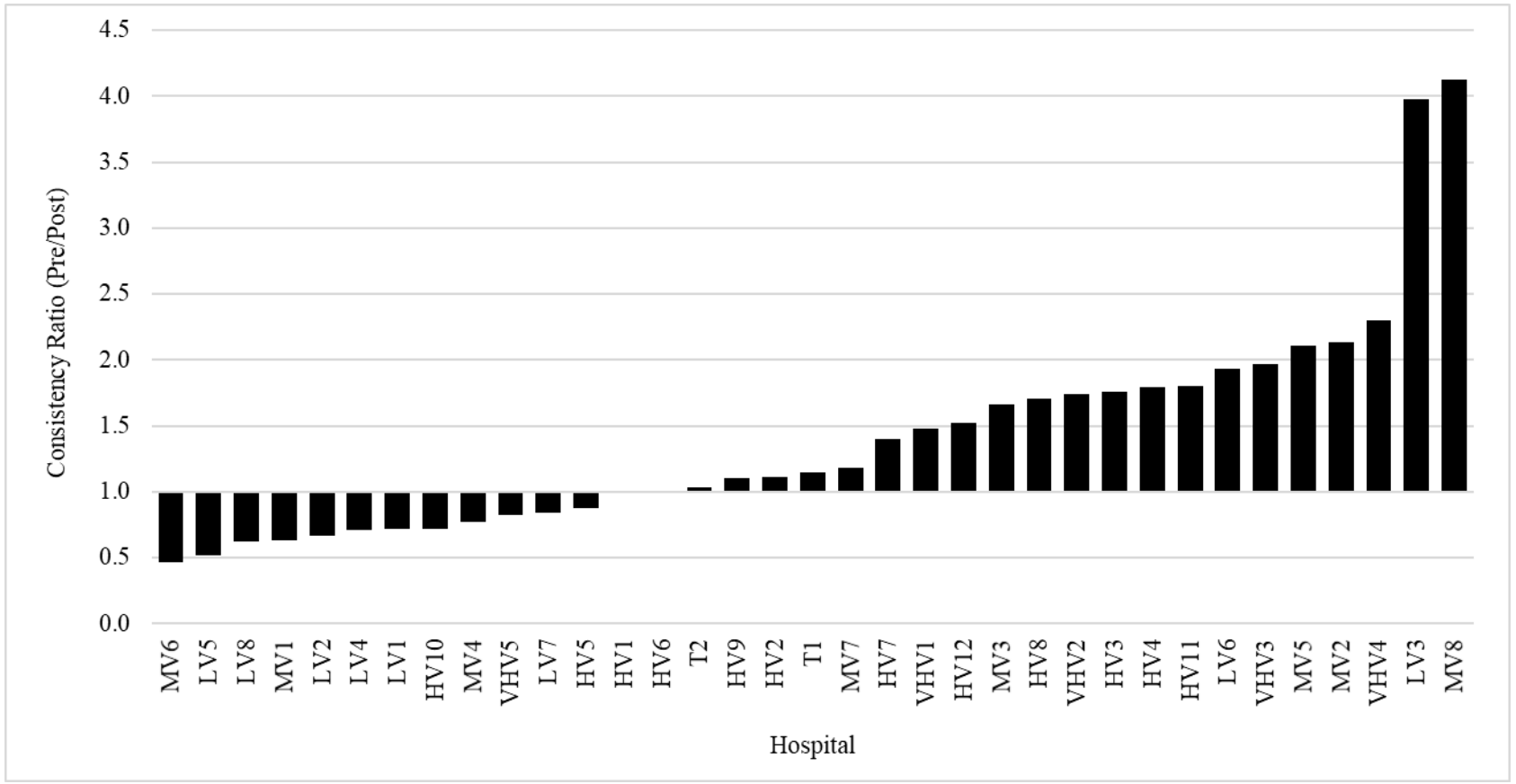
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 23. Consistency ratios by presenting complaint "General Weakness" for 35 hospitals across Ontario.



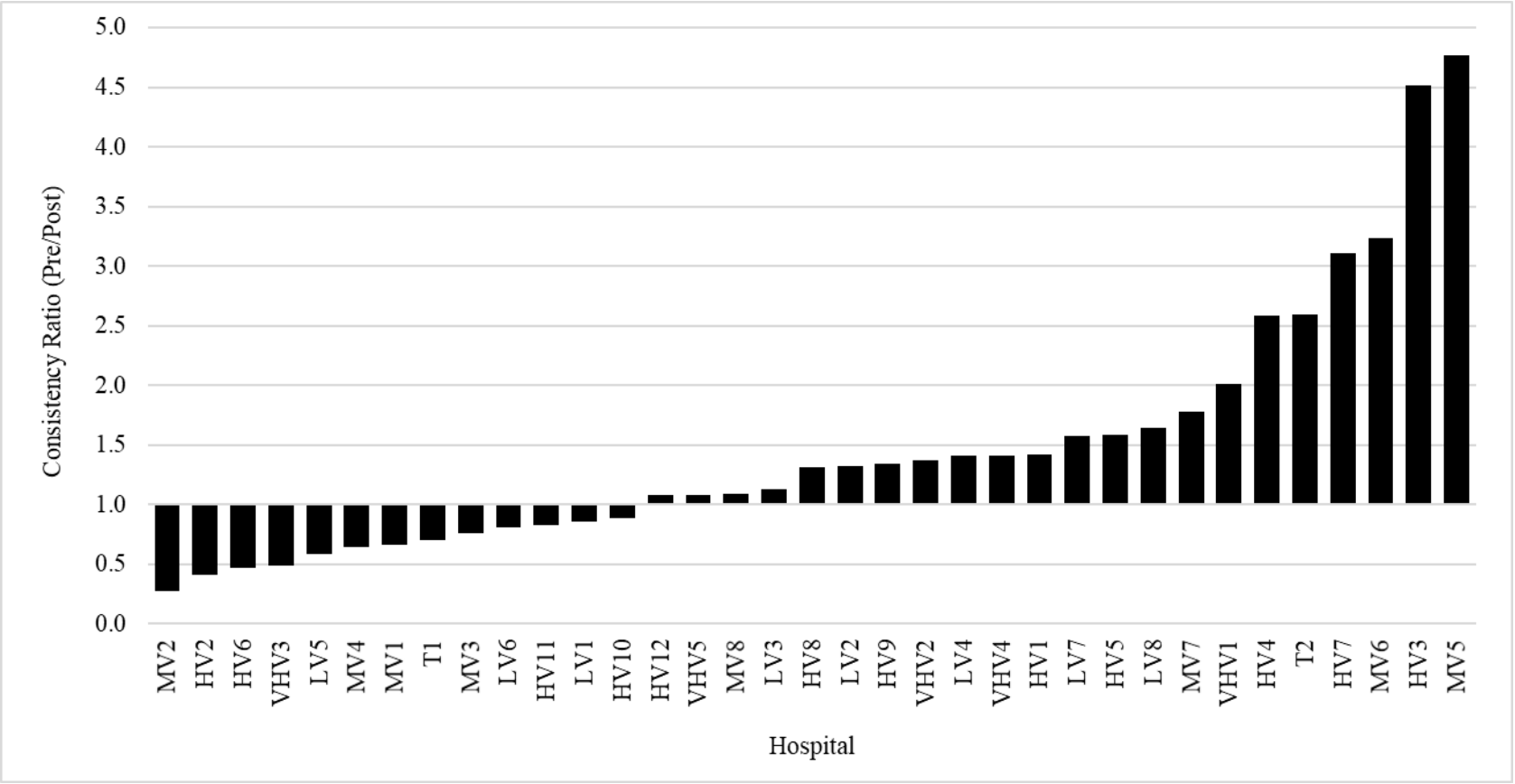
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 24. Consistency ratios by presenting complaint "Head Injury" for 35 hospitals across Ontario.



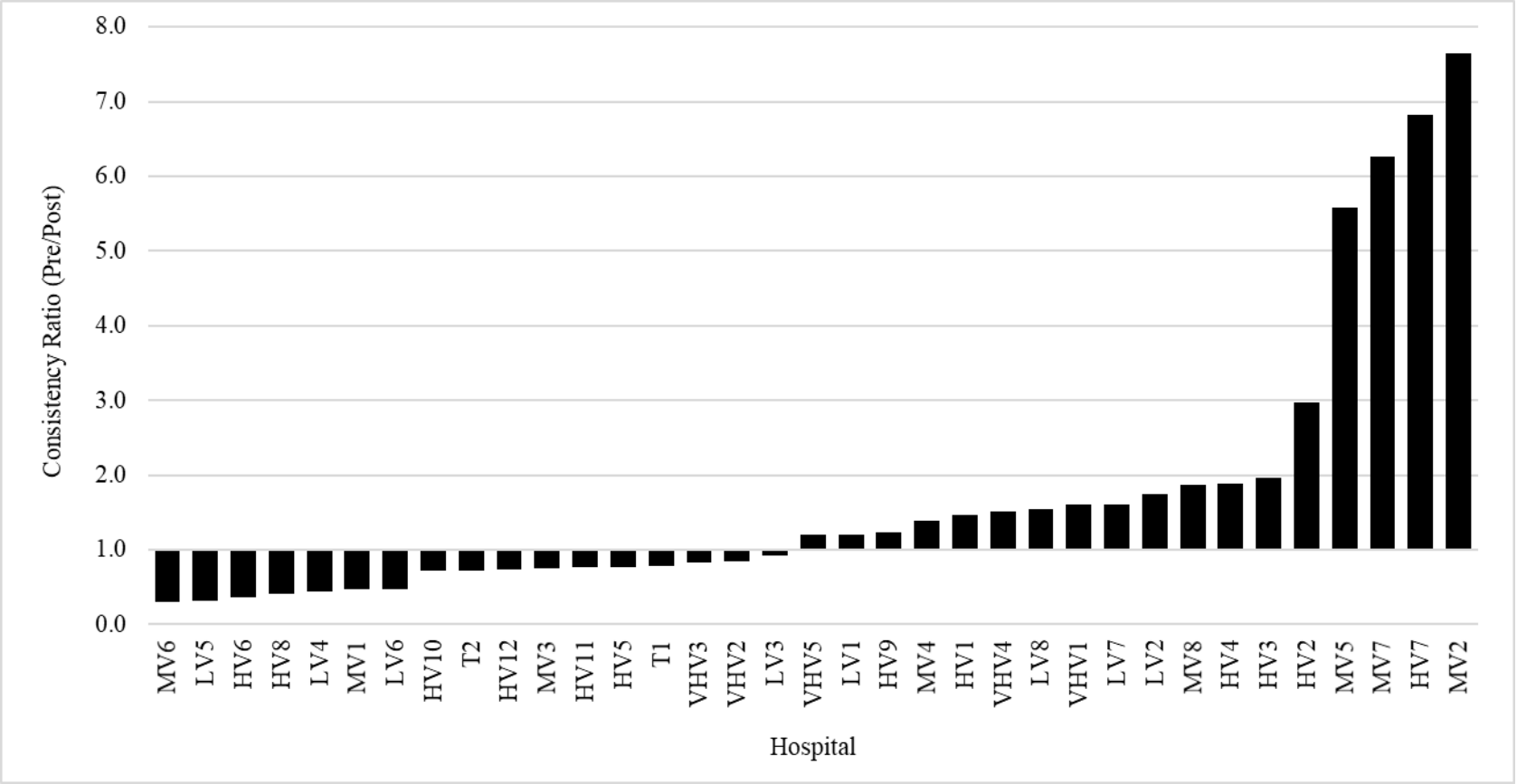
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 25. Consistency ratios by presenting complaint "Hyperglycemia" for 35 hospitals across Ontario.



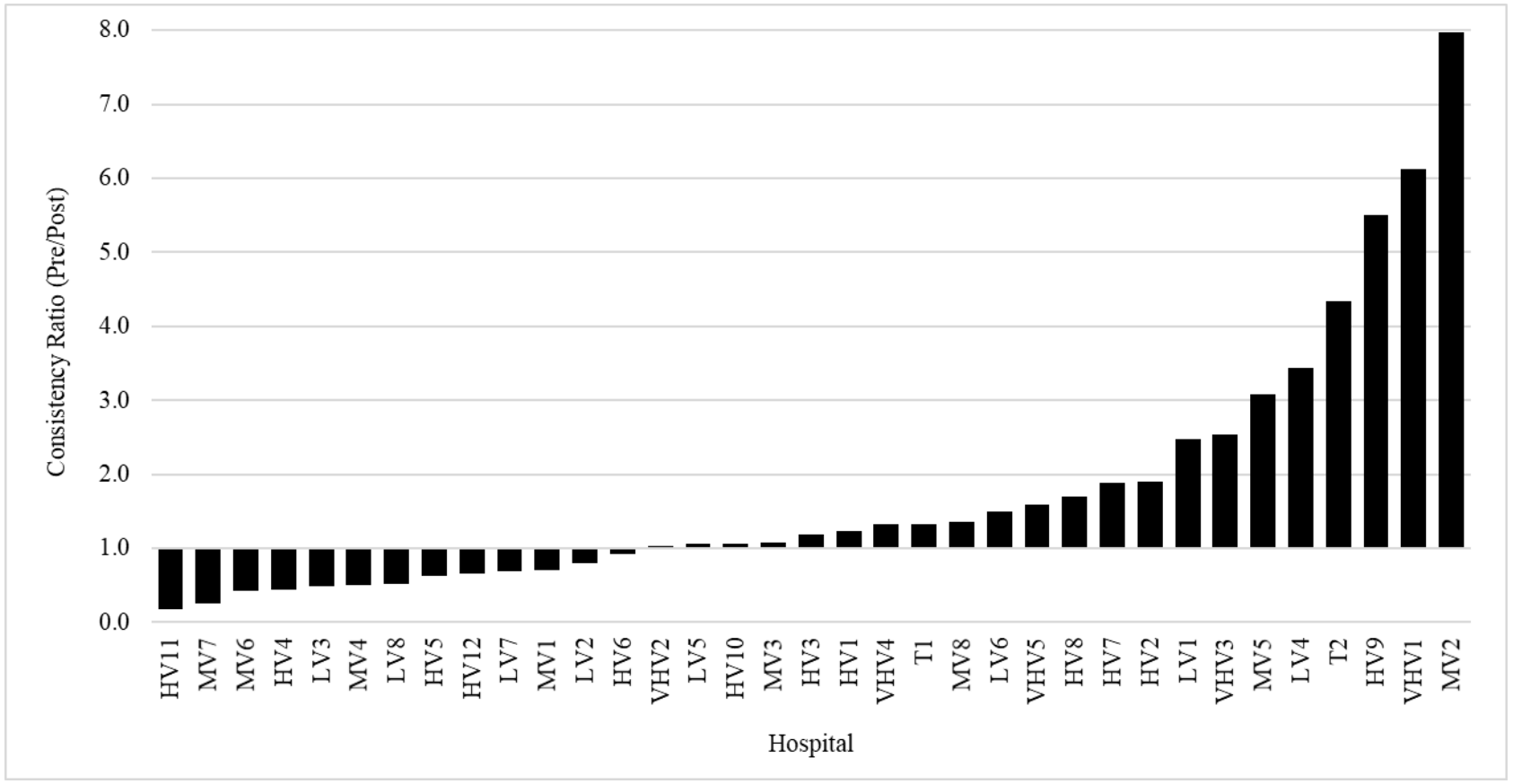
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 26. Consistency ratios by presenting complaint "Palpitations / Irregular Heartbeat" for 35 hospitals across Ontario.



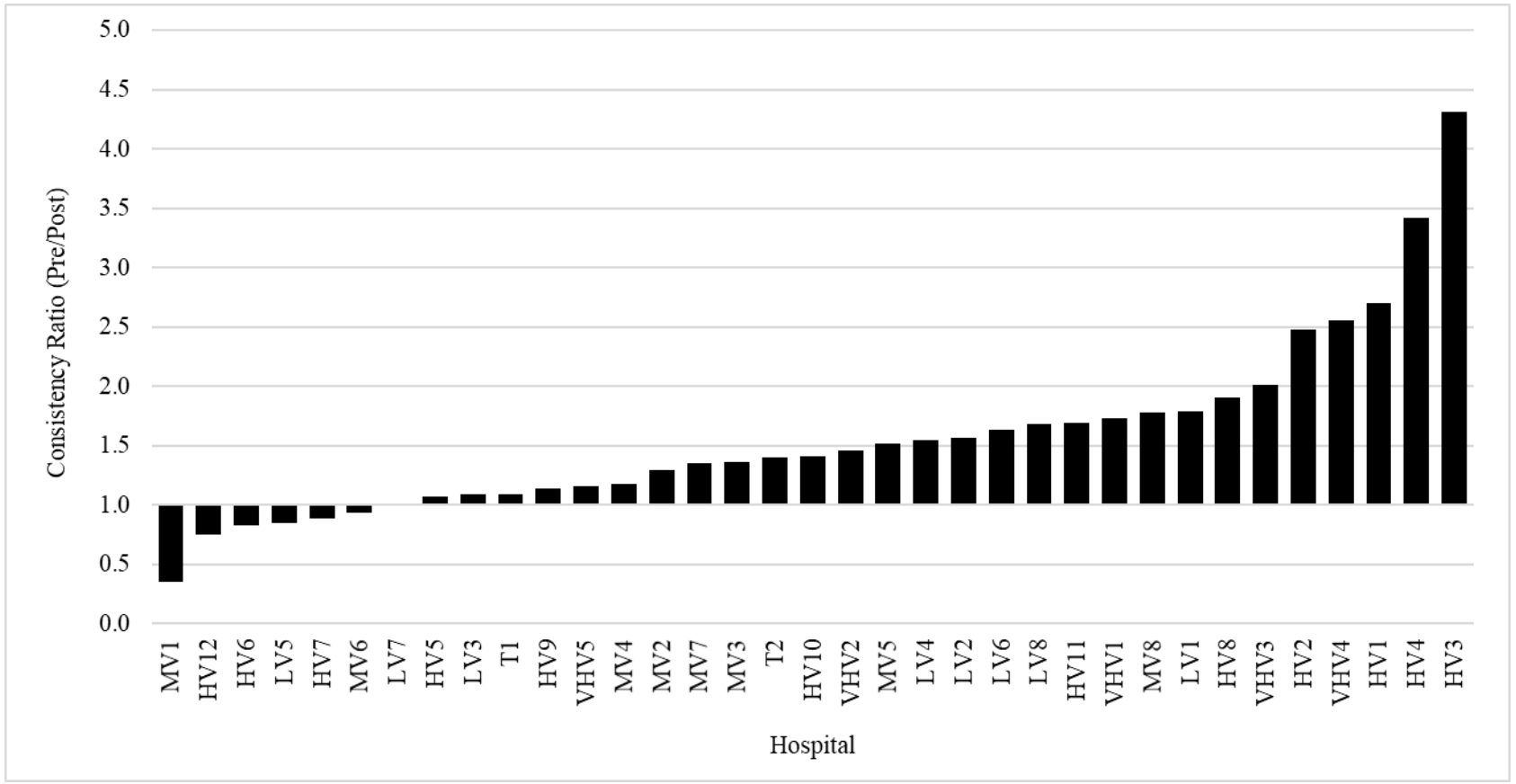
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 27. Consistency ratios by presenting complaint "Seizure" for 35 hospitals across Ontario.



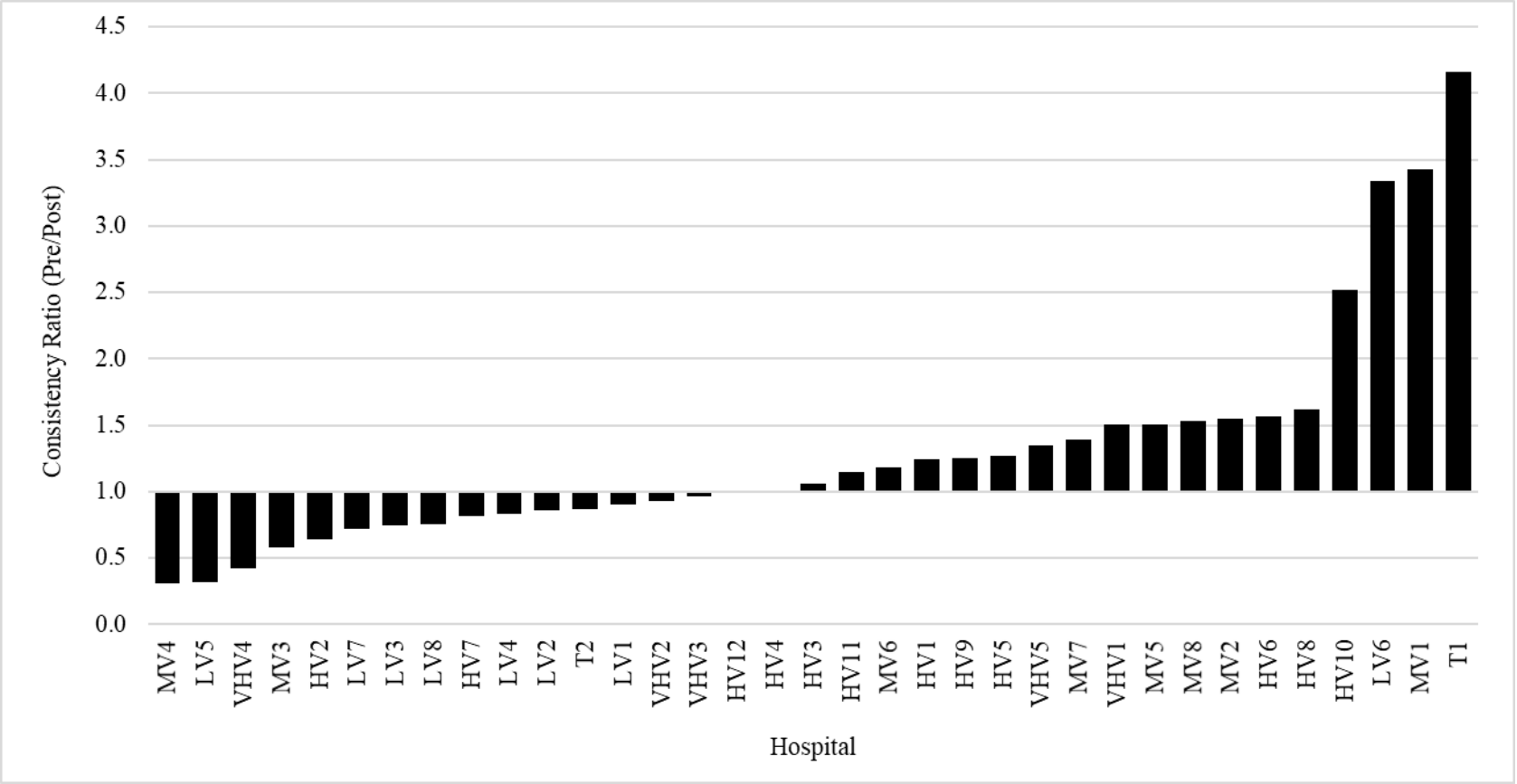
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 28. Consistency ratios by presenting complaint "Shortness of Breath" for 35 hospitals across Ontario.



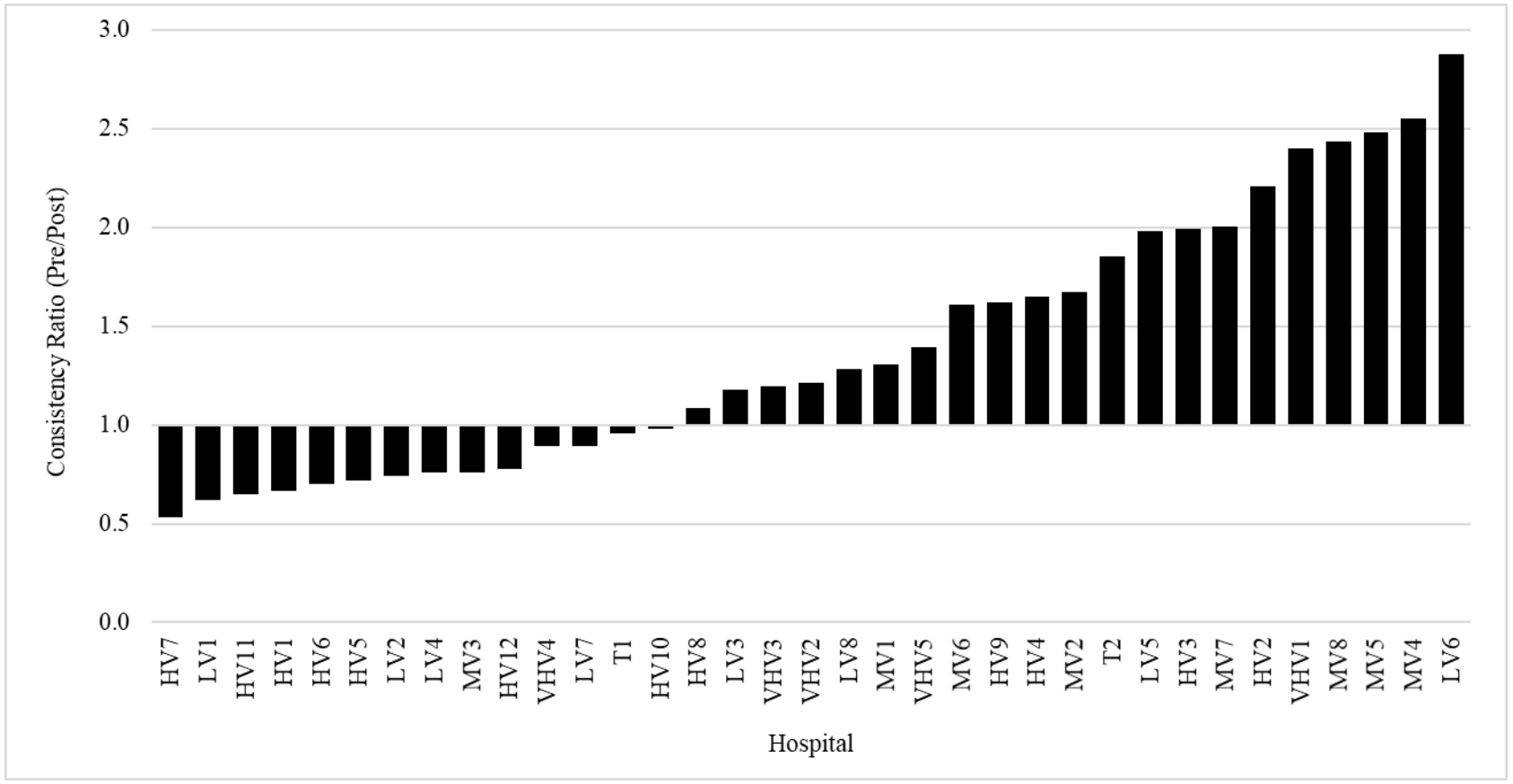
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 29. Consistency ratios by presenting complaint "Substance Misuse / Intoxication" for 35 hospitals across Ontario.



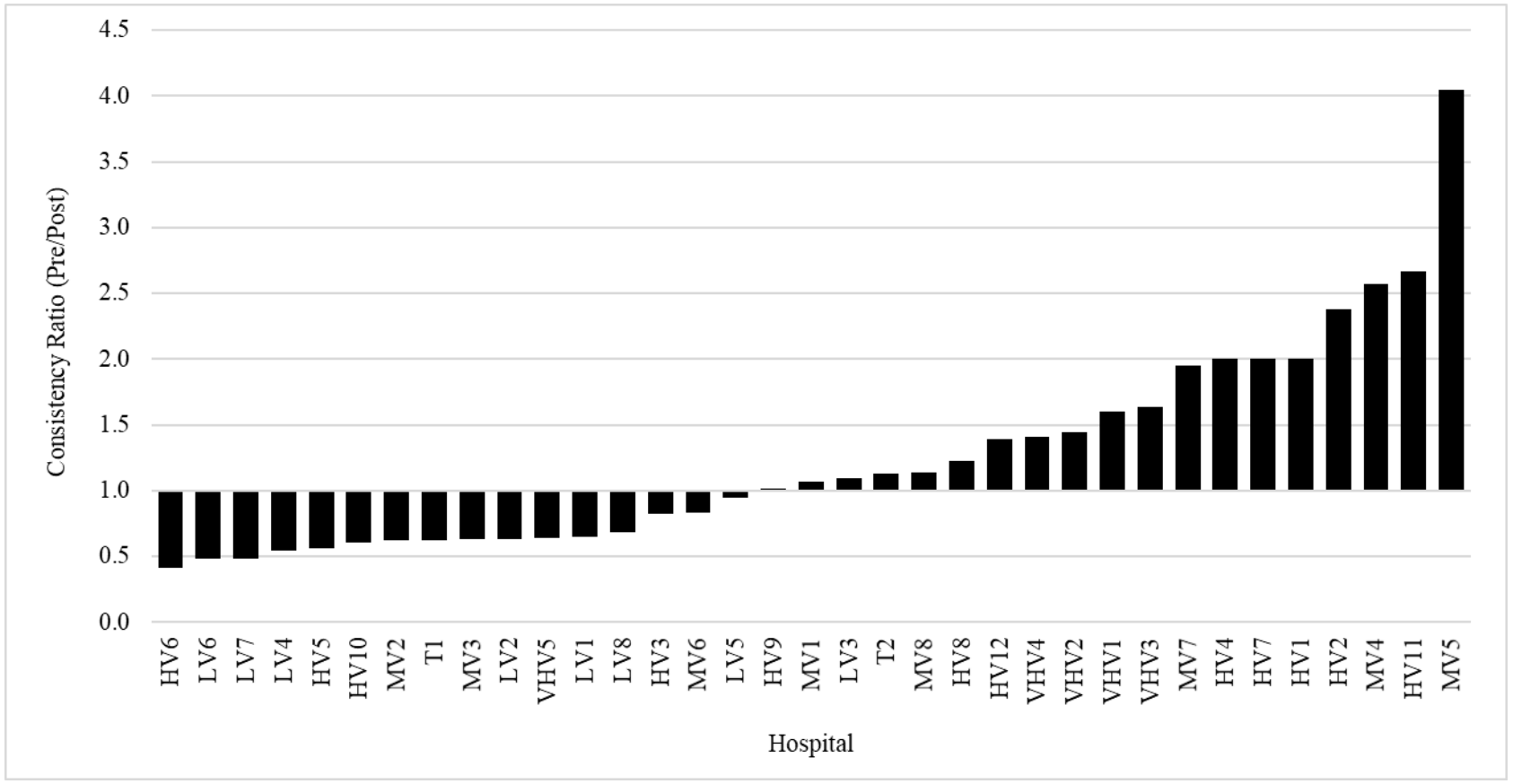
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 30. Consistency ratios by presenting complaint "Syncope / Pre-syncope" for 35 hospitals across Ontario.



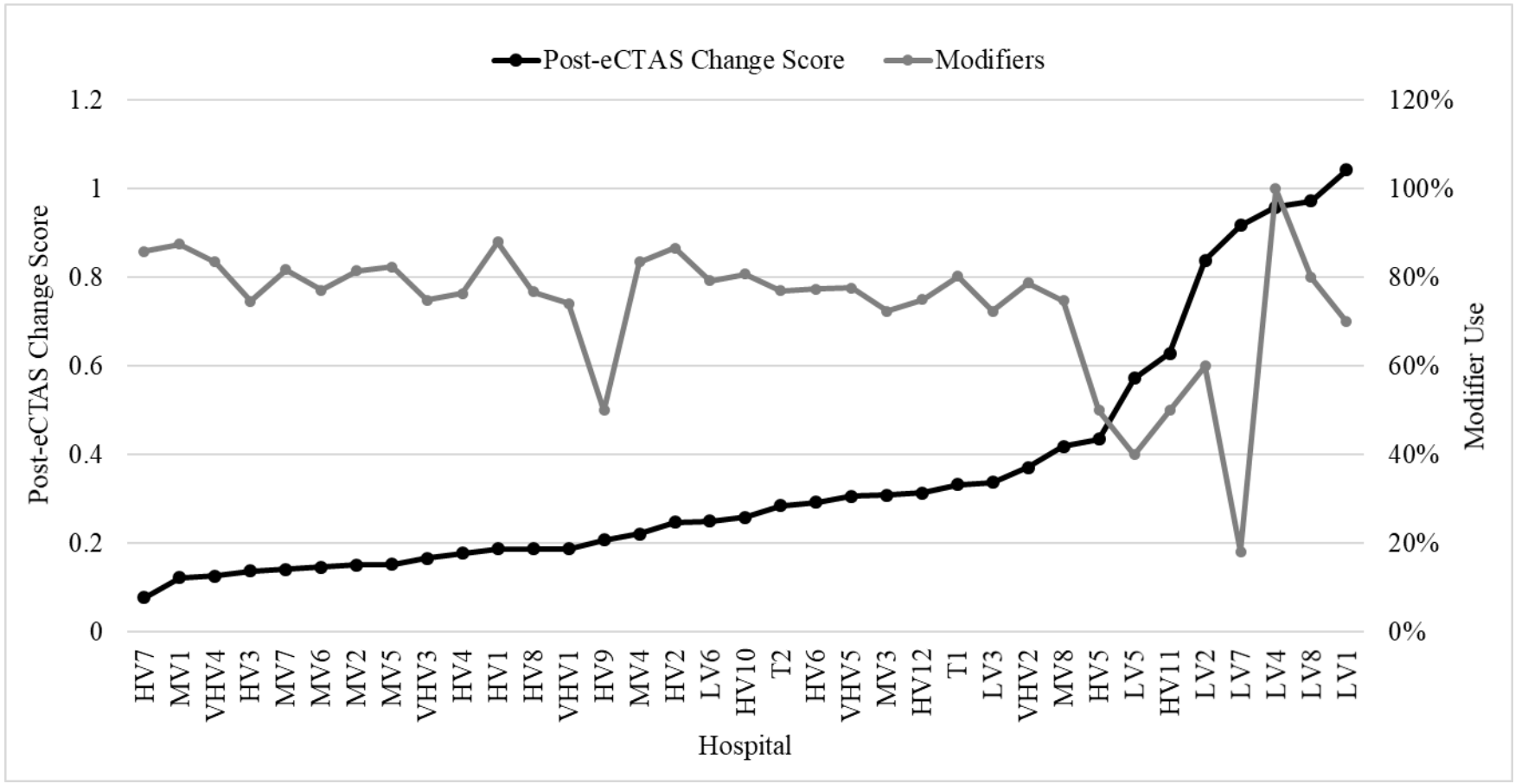
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 31. Consistency ratios by presenting complaint "Vertigo" for 35 hospitals across Ontario.



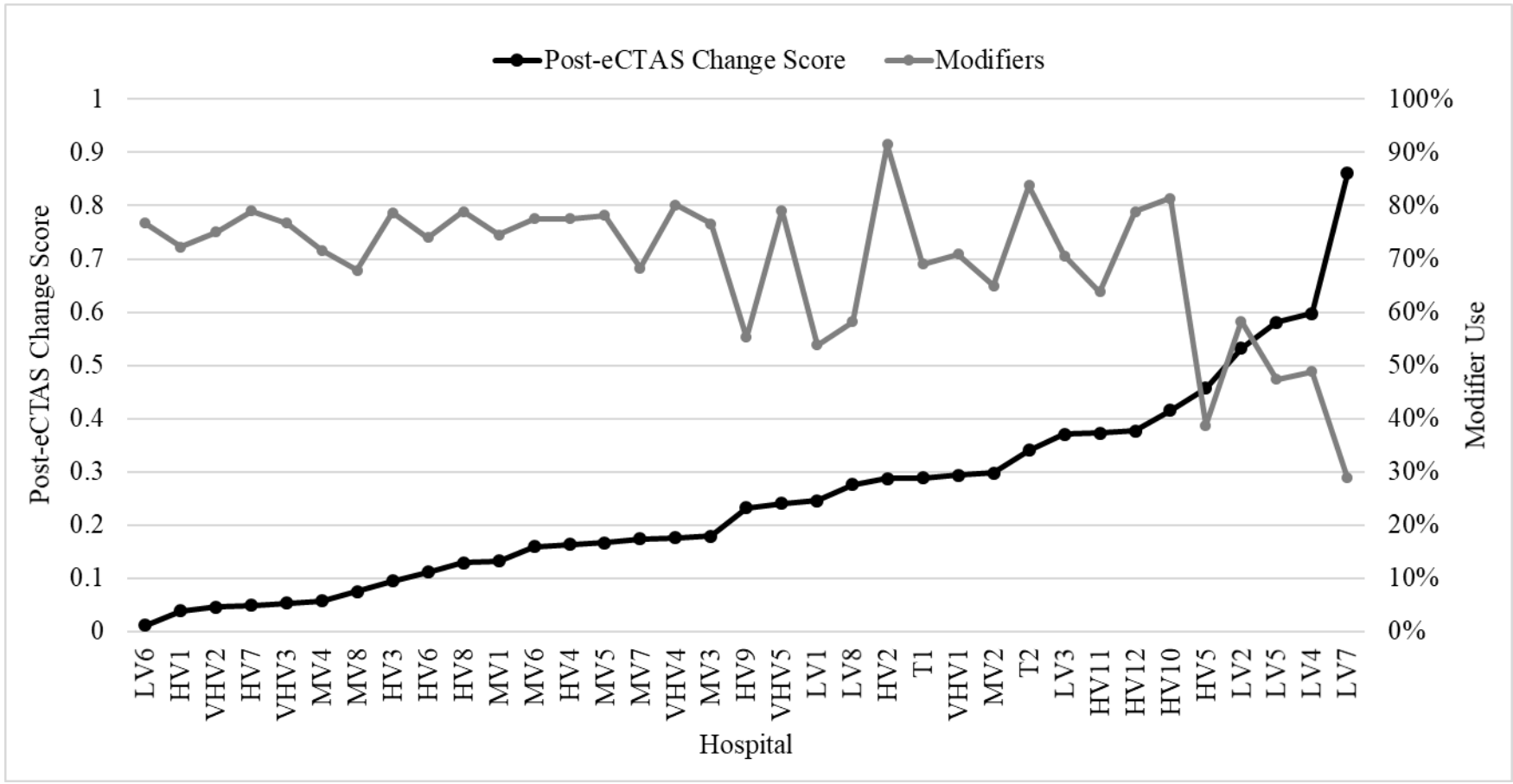
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 32. Post-eCTAS change score and use of modifiers by presenting complaint "Altered Level of Consciousness" for 35 hospitals across Ontario.



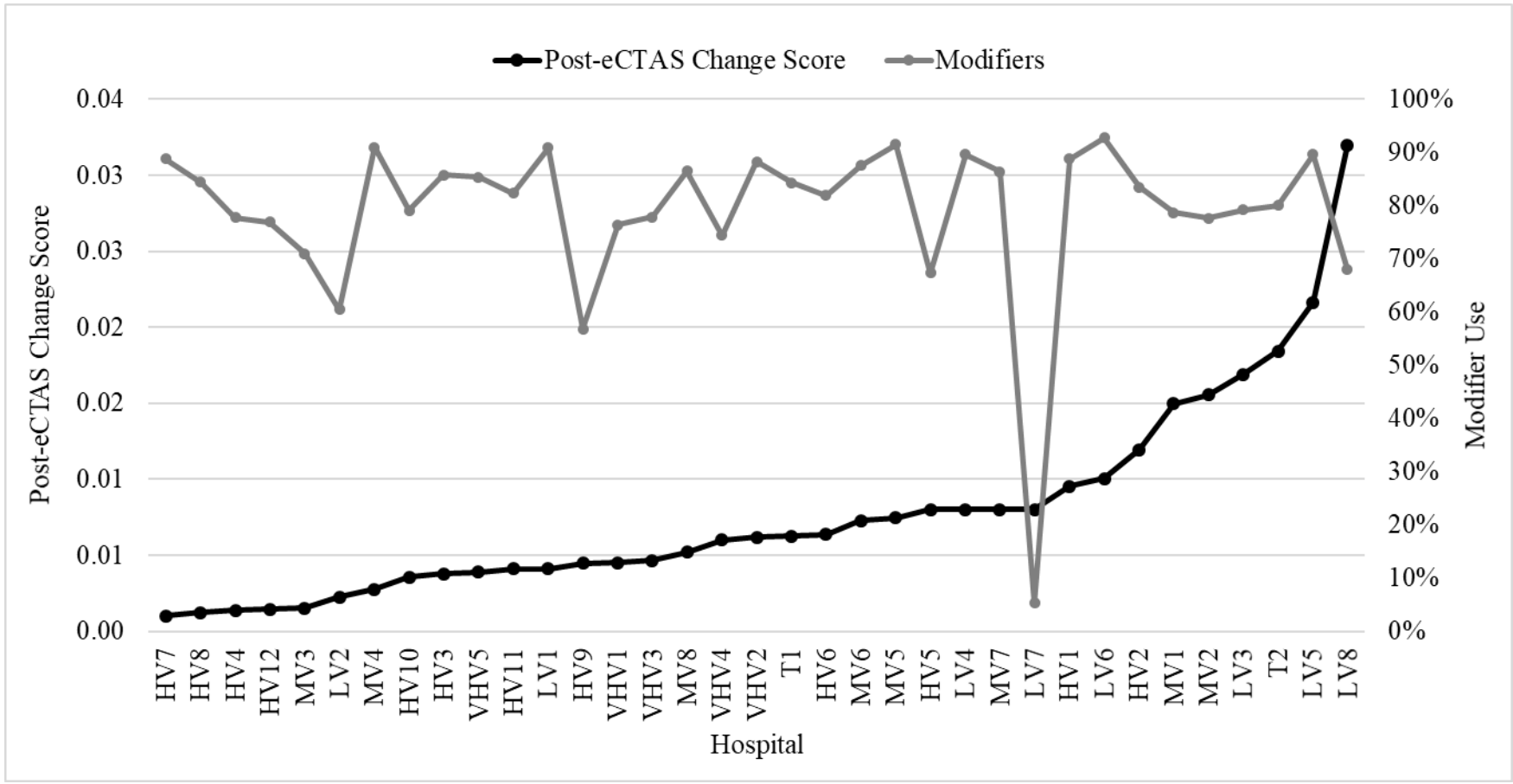
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 33. Post-eCTAS change score and use of modifiers by presenting complaint "Anxiety/Situational Crisis" for 35 hospitals across Ontario.



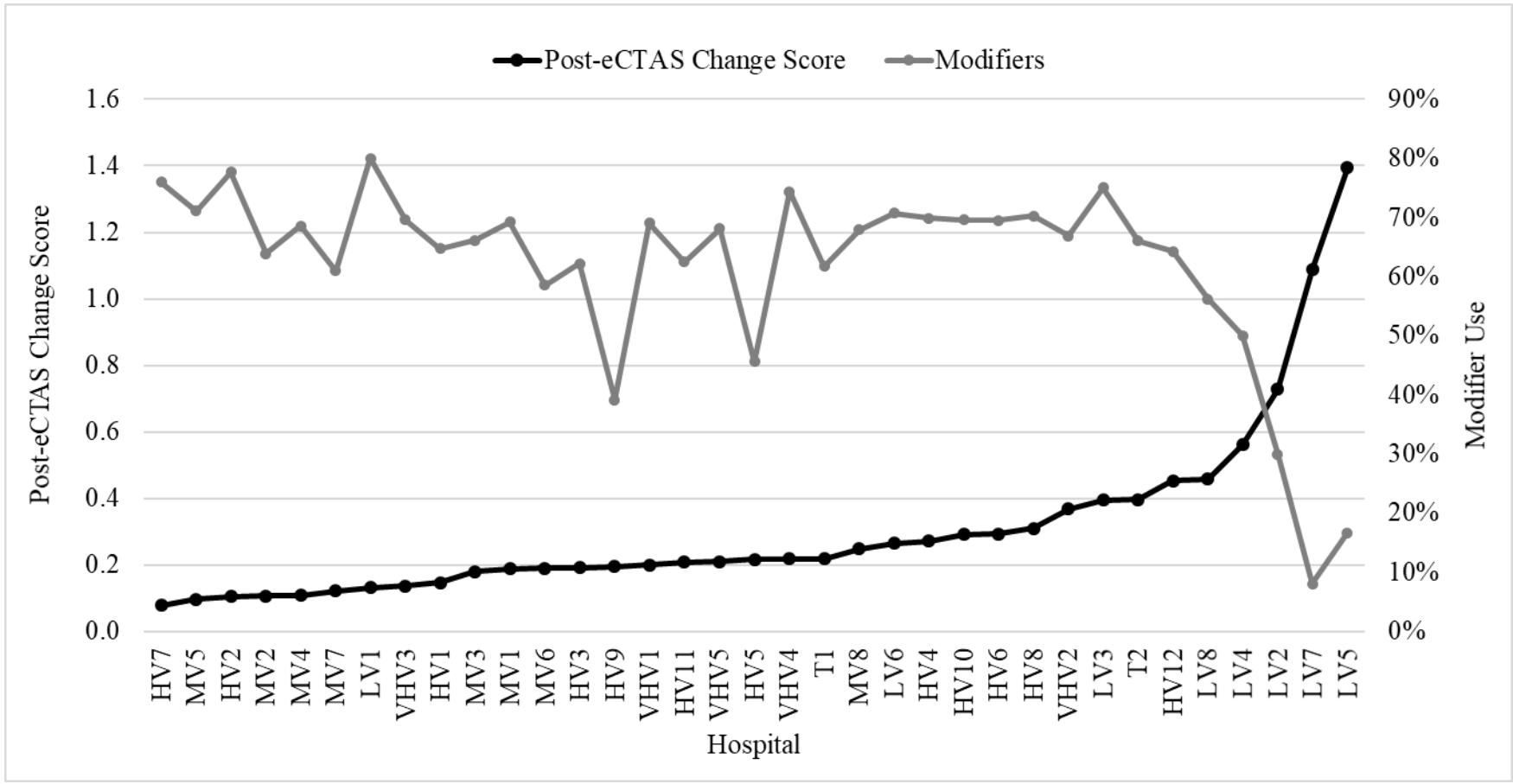
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 34. Post-eCTAS change score and use of modifiers by presenting complaint "Chest Pain Cardiac Features" for 35 hospitals across Ontario.



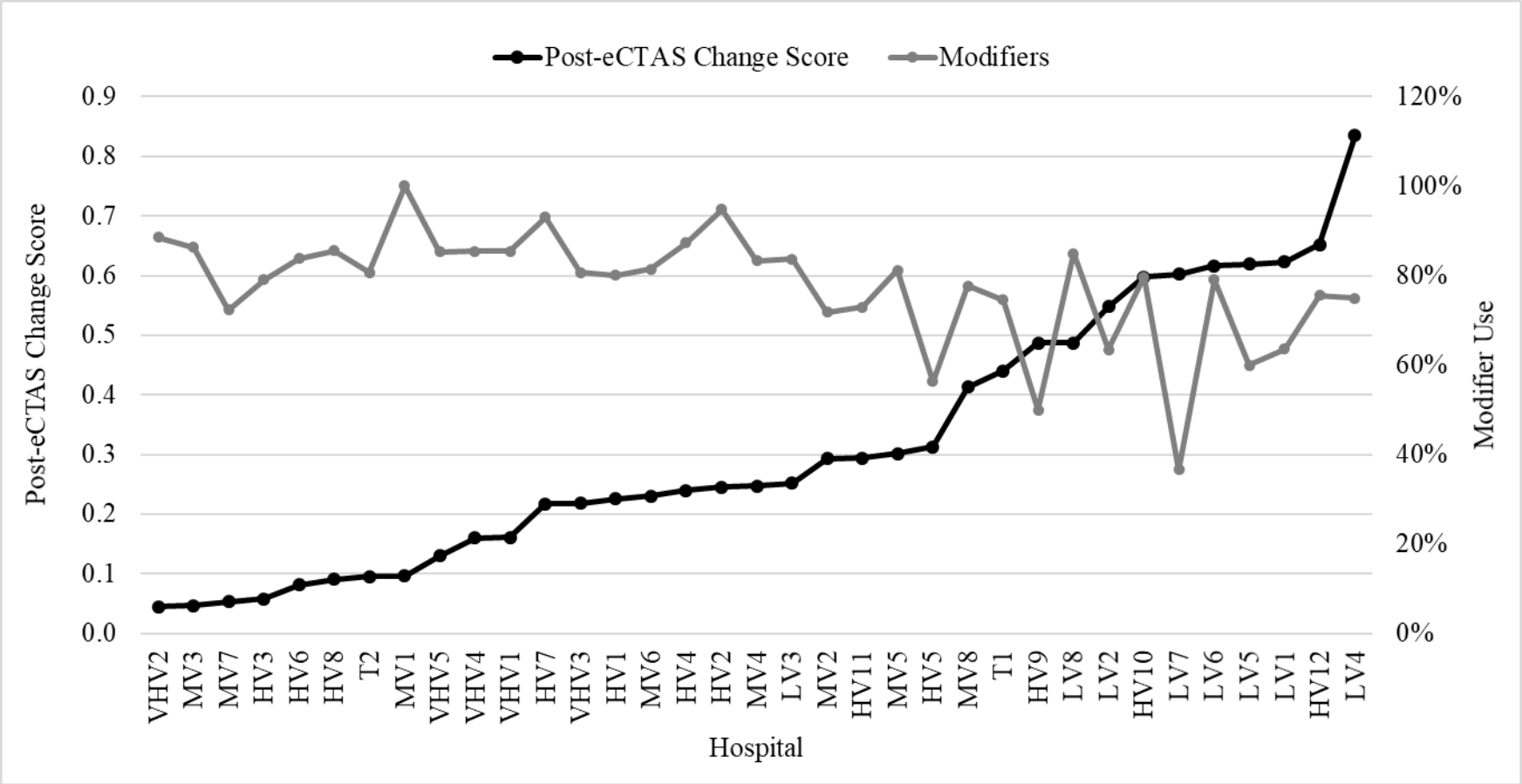
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 35. Post-eCTAS change score and use of modifiers by presenting complaint "Confusion" for 35 hospitals across Ontario.



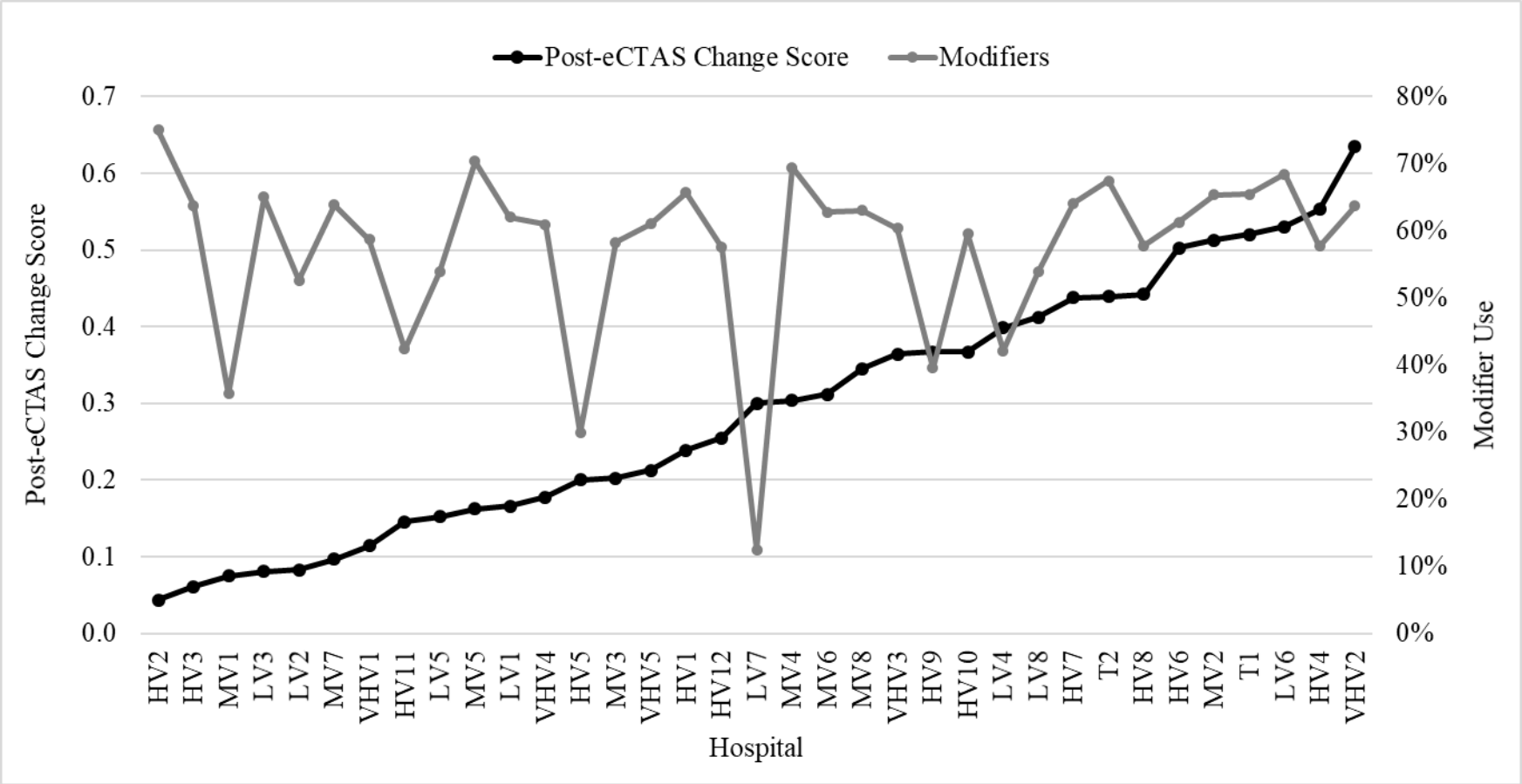
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 36. Post-eCTAS change score and use of modifiers by presenting complaint "Depression/Suicidal/Deliberate Self Harm" for 35 hospitals across Ontario.



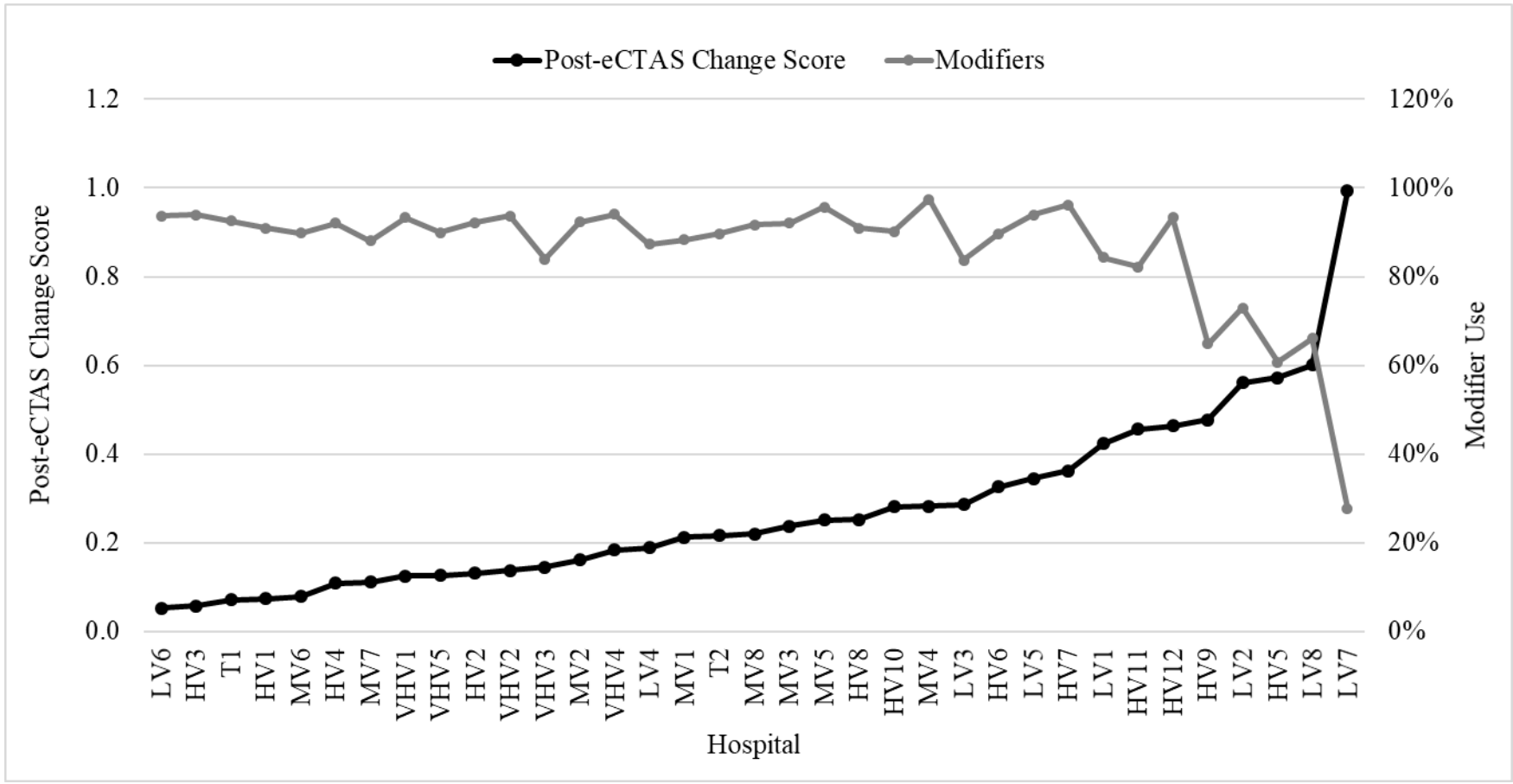
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 37. Post-eCTAS change score and use of modifiers by presenting complaint "Extremity Weakness/Symptoms of CVA" for 35 hospitals across Ontario.



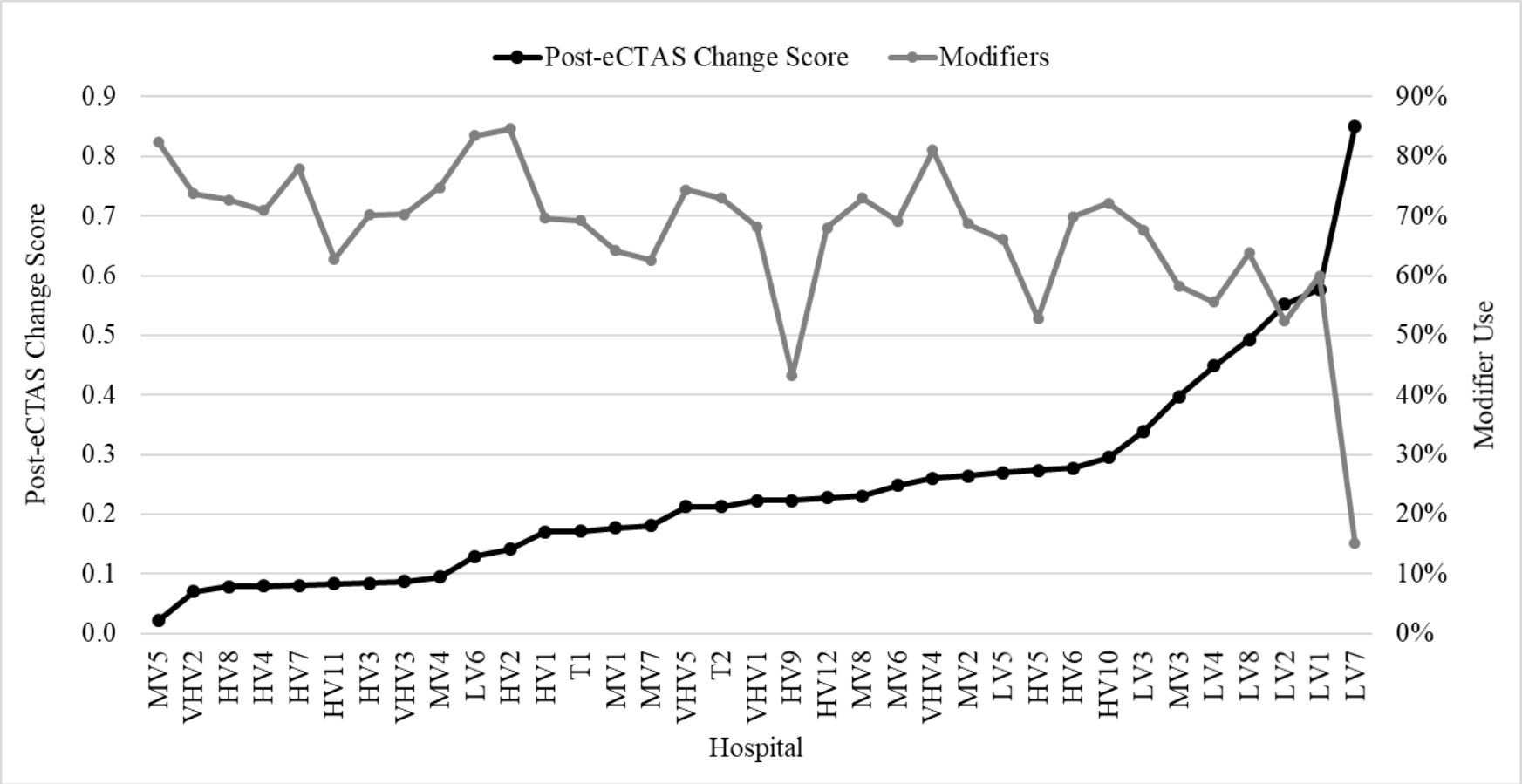
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 38. Post-eCTAS change score and use of modifiers by presenting complaint "Fever" for 35 hospitals across Ontario.



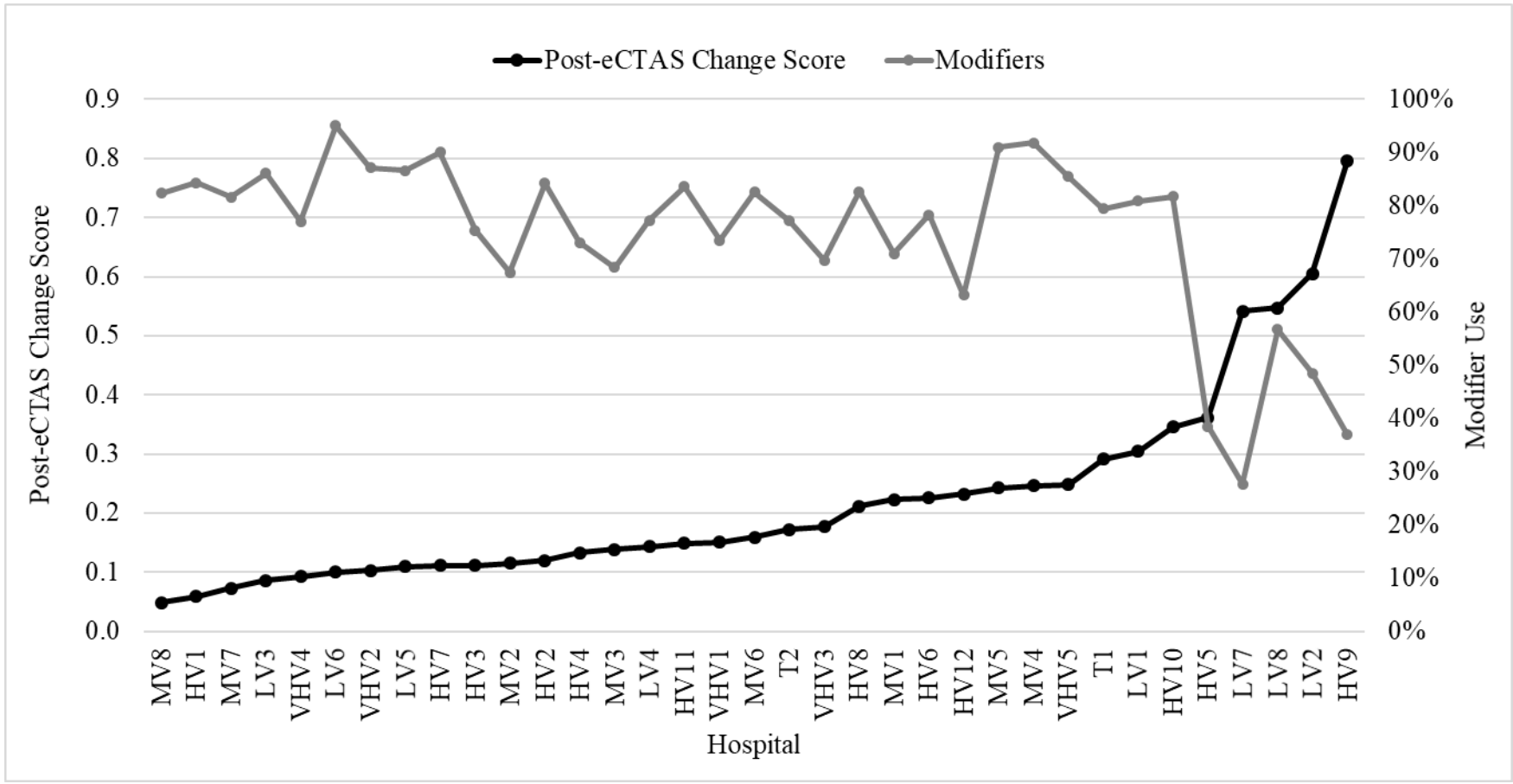
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 39. Post-eCTAS change score and use of modifiers by presenting complaint "General Weakness" for 35 hospitals across Ontario.



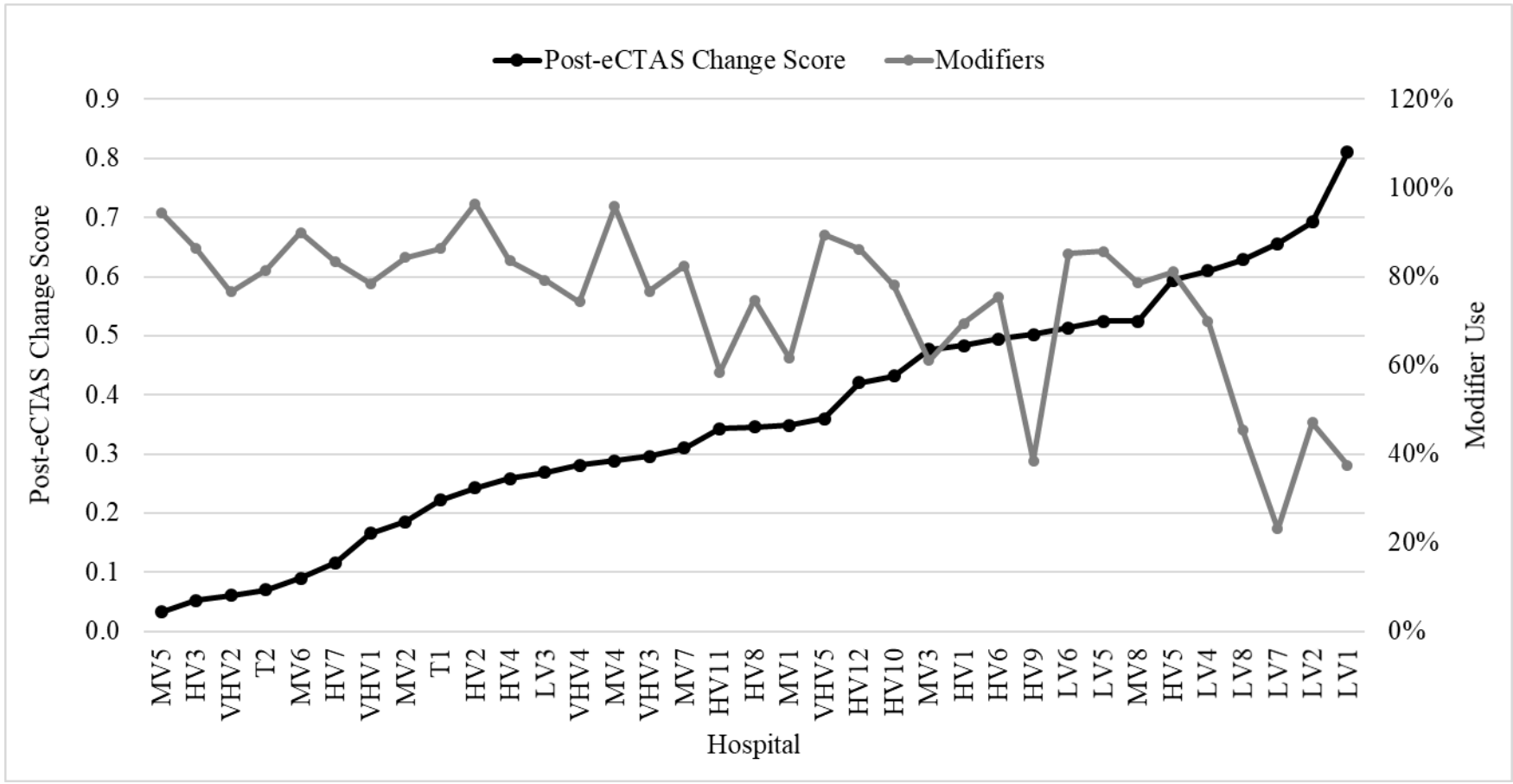
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 40. Post-eCTAS change score and use of modifiers by presenting complaint "Head Injury" for 35 hospitals across Ontario.



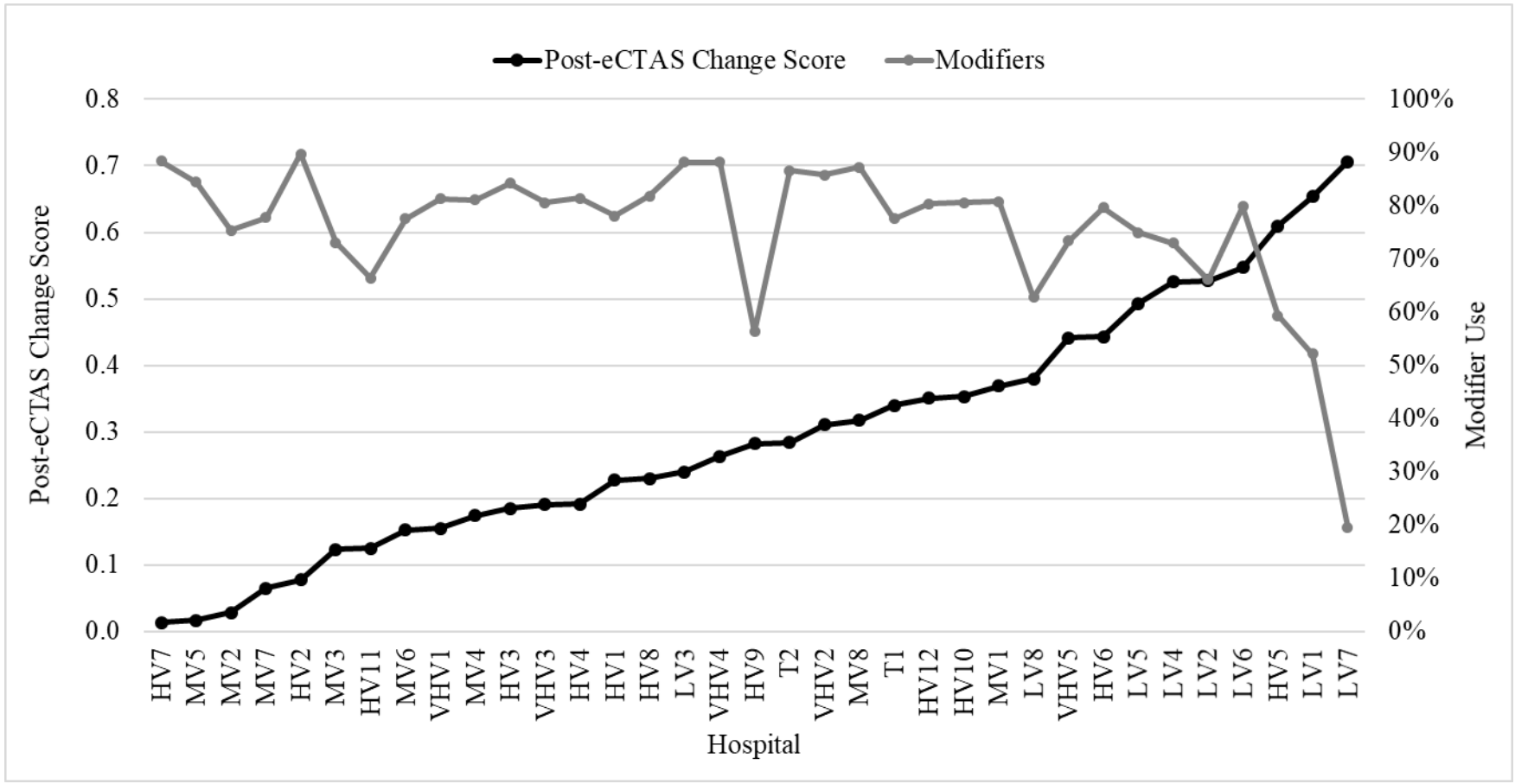
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 41. Post-eCTAS change score and use of modifiers by presenting complaint "Hyperglycemia" for 35 hospitals across Ontario.



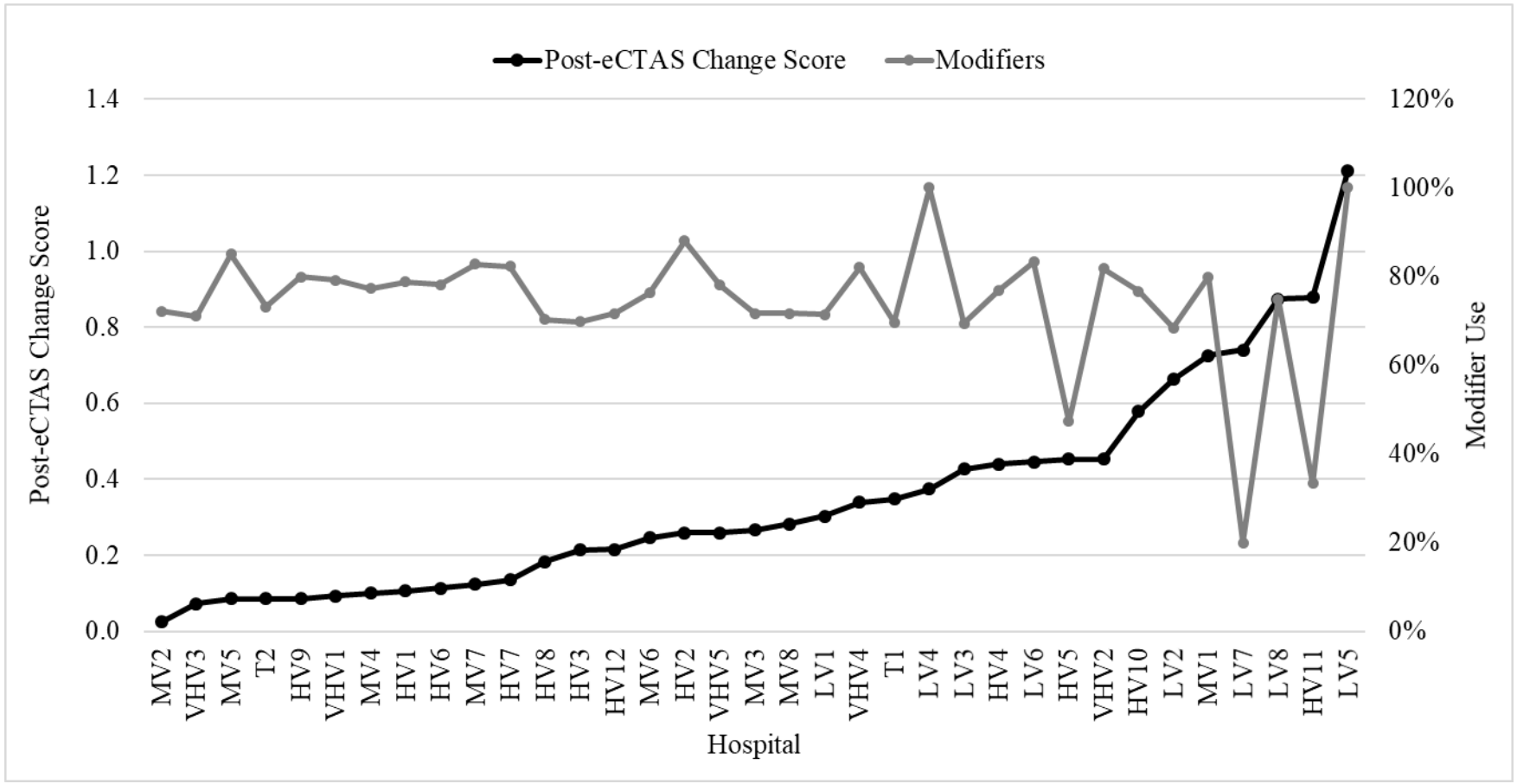
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 42. Post-eCTAS change score and use of modifiers by presenting complaint "Palpitations/Irregular Heartbeat" for 35 hospitals across Ontario.



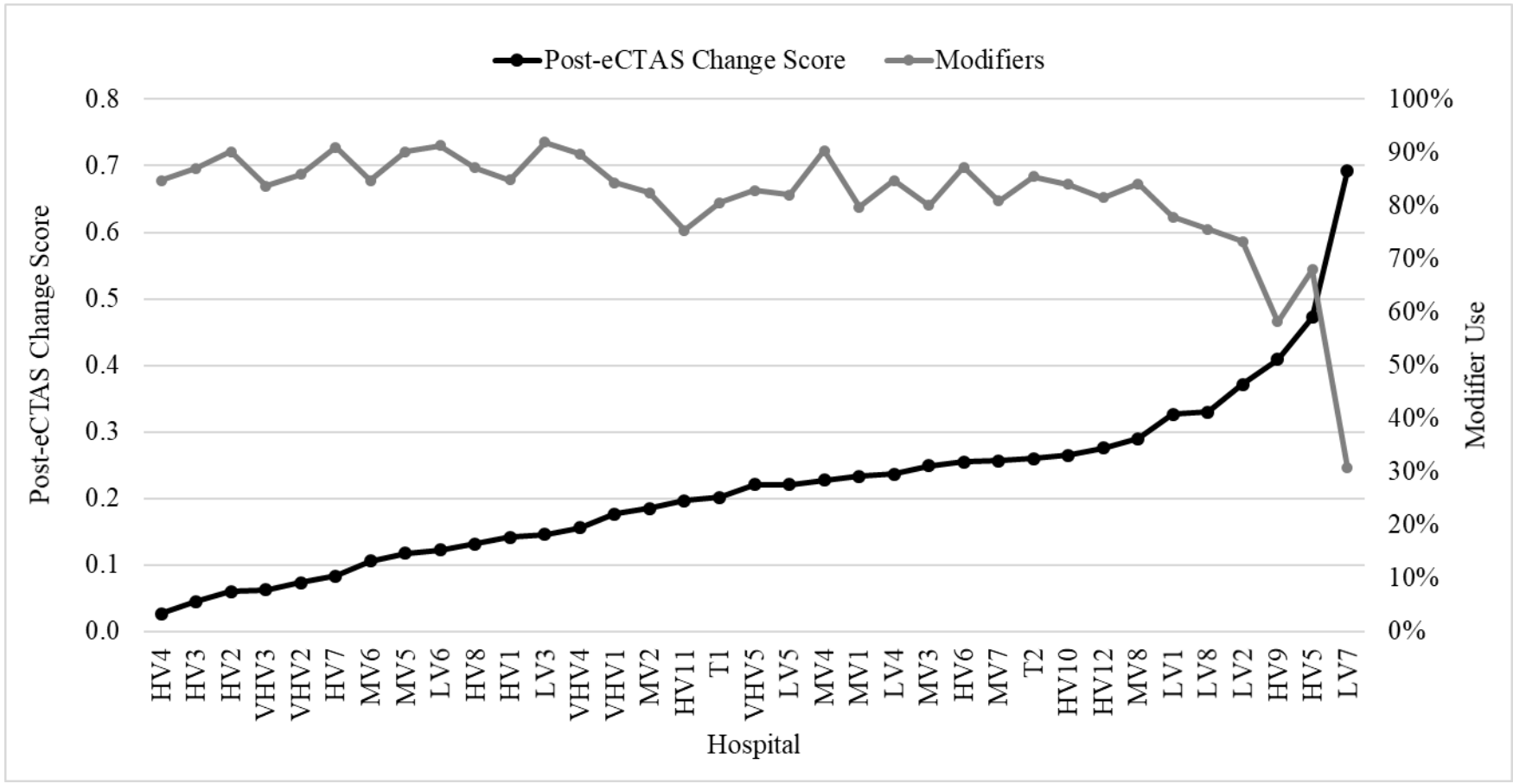
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 43. Post-eCTAS change score and use of modifiers by presenting complaint "Seizure" for 35 hospitals across Ontario.



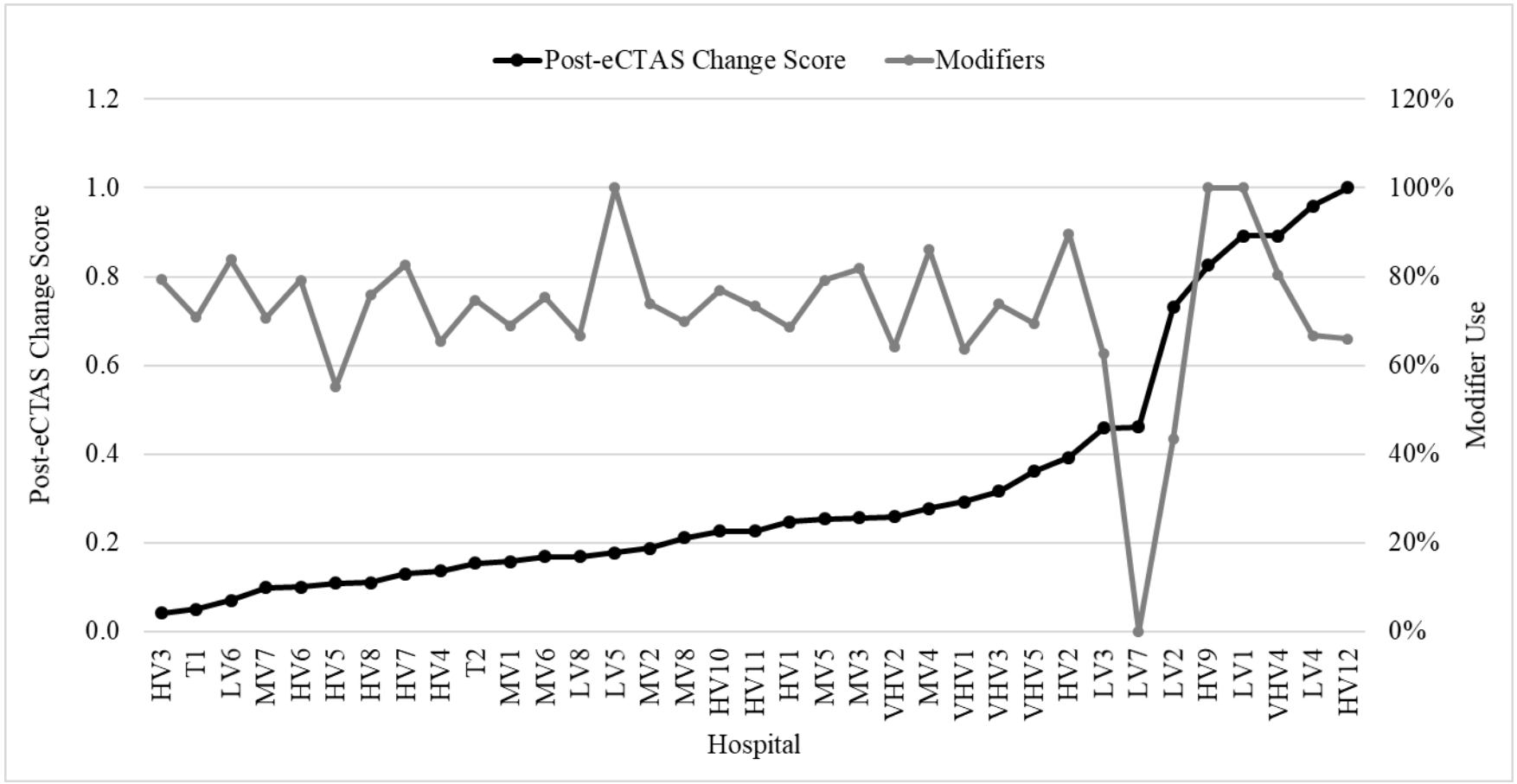
Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 44. Post-eCTAS change score and use of modifiers by presenting complaint "Shortness of Breath" for 35 hospitals across Ontario.

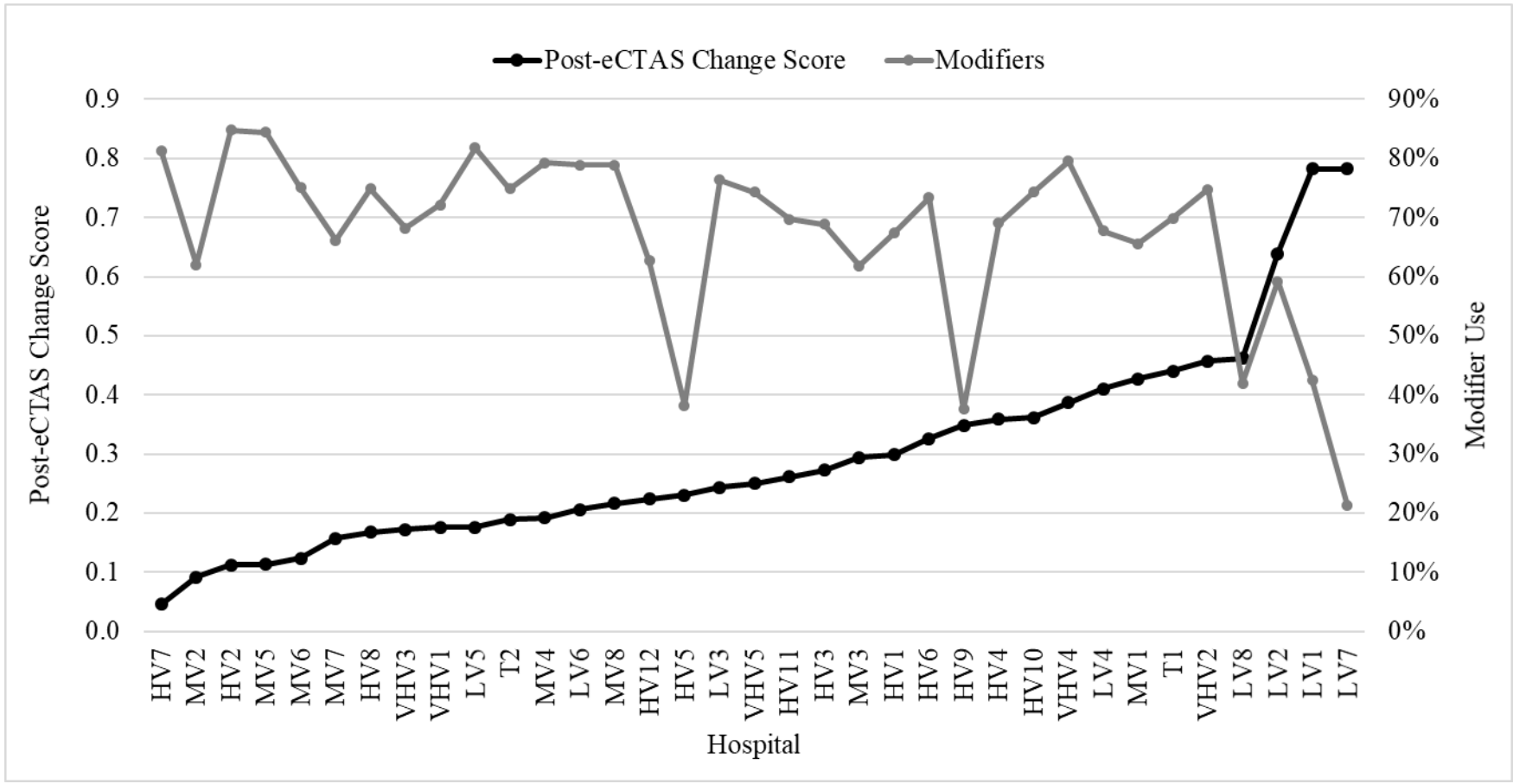


Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 45. Post-eCTAS change score and use of modifiers by presenting complaint "Substance Misuse/Intoxication" for 35 hospitals across Ontario.

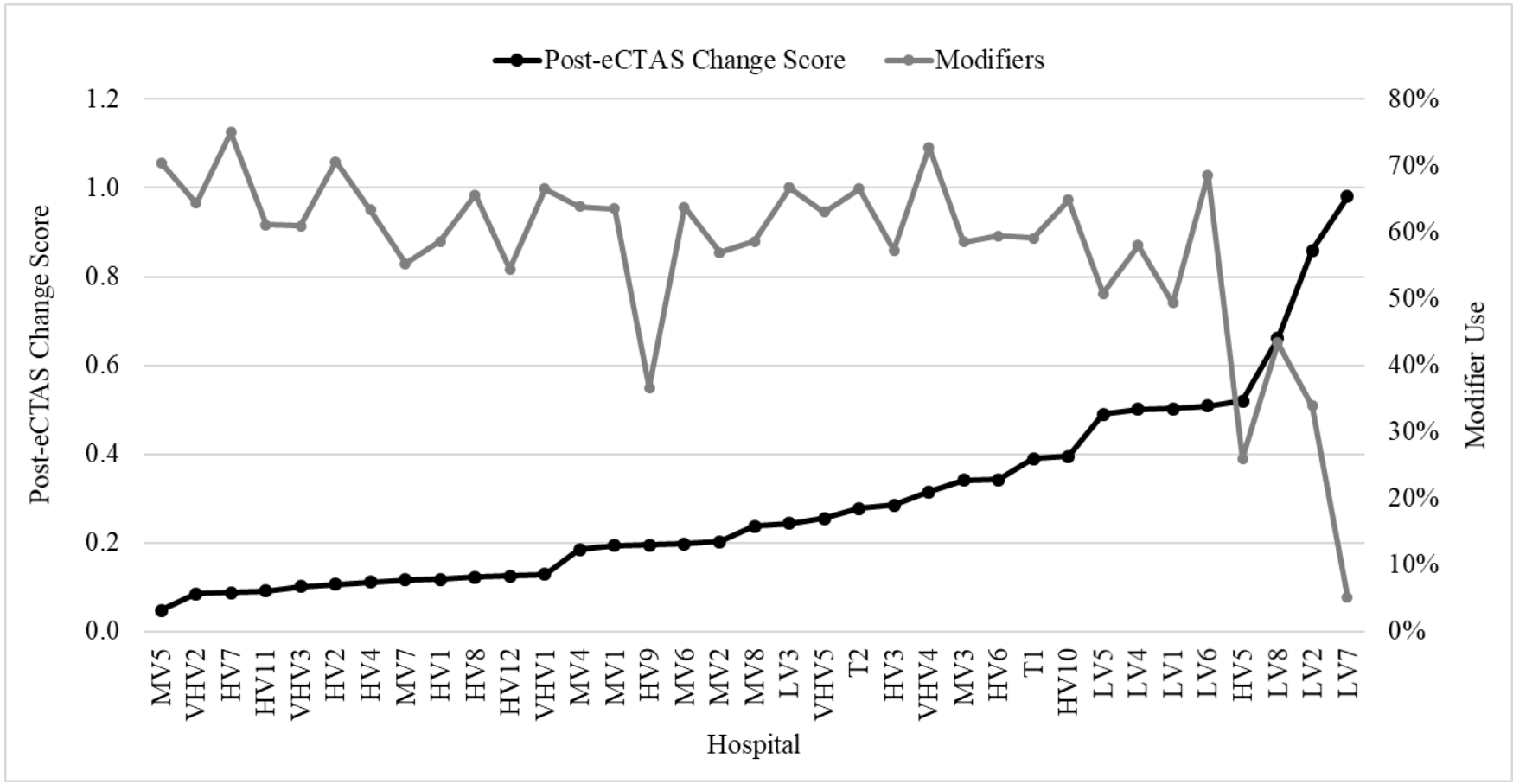


Supplementary Figure 46. Post-eCTAS change score and use of modifiers by presenting complaint "Syncope/Pre-syncope" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

Supplementary Figure 47. Post-eCTAS change score and use of modifiers by presenting complaint "Vertigo" for 35 hospitals across Ontario.



Where: LV = low volume; MV = medium volume; HV = high volume; VHV = very high volume; T = teaching.

CHAPTER 4: INFLUENCE OF ELECTRONIC TRIAGE DECISION-SUPPORT ON HOSPITAL ADMISSION, LEFT WITHOUT BEING SEEN AND TIME TO PHYSICIAN INITIAL ASSESSMENT IN THE EMERGENCY DEPARTMENT.

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ABSTRACT

Background: The objective was to explore the possible impact of the implementation of eCTAS, a real-time electronic decision-support tool, on hospital admission, rate of left without being seen (LWBS), and time from triage to physician initial assessment (PIA).

Methods: We conducted a retrospective cohort study using population-based administrative data from all Ontario EDs that had implemented eCTAS for 9 months. We compared 6 months post-eCTAS data to the same 6-months the previous year (pre-eCTAS). We included triage encounters of adult (≥18 years) patients if they had one of 16 pre-specified, high-volume presenting complaints. Multivariable logistic regression and quantile regression models informed the possible effect of eCTAS on outcomes.

Results: We included data from 354,176 triage encounters from 31 EDs. There was a change in the distribution of triage scores post-CTAS, with fewer patients classified as CTAS 2 and CTAS 3, and more patients classified as CTAS 4. Overall, hospital admission decreased post-eCTAS (adjusted OR: 0.98; 95% CI: 0.97 to 1.00), with fewer CTAS 2 and more CTAS 3 and CTAS 4 patients admitted post-eCTAS. LWBS increased (2.8% vs 3.0%; adjusted OR: 1.07; 95% CI: 1.03 to 1.11) post-eCTAS, while time to PIA proved similar pre and post-eCTAS. In terms of attribution of differences to eCTAS, evidence proved low quality in all cases.

Interpretation: eCTAS implementation had little impact on hospital admission, LWBS and time to PIA. eCTAS appears to reclassify patients from higher to lower acuity scores, resulting in higher admission rates for CTAS 3 and CTAS 4 patients. It remains unknown if this reclassification is appropriate.

Introduction

Ontario is Canada's most populous province, with approximately 14.6 million people and 135 emergency departments (EDs). In 2018/19, Ontarians seeking medical attention made over 6 million (6,066,900) visits to an ED.<1> The ED evaluation begins at arrival, when patients undergo triage by ED personnel and are assigned a priority score based on perceived clinical urgency. The Canadian Triage and Acuity Scale (CTAS) is the triage standard used in all Canadian and many international EDs to determine the priority by which patients should be assessed by a healthcare provider.<2-12> The scale delineates 5 levels of acuity: level 1 (resuscitation), level 2 (emergent), level 3 (urgent), level 4 (less urgent) and level 5 (non-urgent).

Many provincial governments also use CTAS as an administrative metric to estimate patient care requirements, compare ED performance, and estimate ED physician staffing needs.<13-16> Despite the use of CTAS guidelines, the process by which CTAS scores are derived varies significantly both within and between EDs.<11,12,17-21>. According to a 2010 report from the Ontario Auditor General, 38% of Ontario ED patients were being "under-triaged", and there was no process in place for government to validate submitted triage scores, resulting in a lack of transparency and accountability for ED funding.<22> In 2015, the Ontario government agreed to fund the development and implementation of a standardized, electronic solution to reduce triage variability across the province.<23>

eCTAS is a real-time electronic decision-support tool, designed to standardize the application of national triage guidelines.<23,24> The application requires the user to select a presenting

complaint from a standardized list of 169 complaints and then displays a CTAS-based template with complaint-specific modifiers (e.g., vital signs, respiratory distress, hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury) to help ensure high risk time-sensitive conditions are not missed.

In a prospective, observational study of 1491 real-time triage encounters in seven EDs, we previously reported that eCTAS improves interrater agreement without substantially increasing triage time.<24> We also found the use of complaint-specific modifiers with eCTAS was associated with increased triage consistency, particularly for non-specific presenting complaints such as shortness of breath, fever and general weakness. However, despite widespread implementation (>90% of EDs) of this government mandated policy, whether eCTAS versus previous triage method has any impact on ED metrics remains unknown.

The objective of this study was to explore the possible effect of eCTAS implementation versus previous triage method on hospital admission, rate of left without being seen (LWBS), and time from triage to physician initial assessment (PIA).

Methods

Study design, setting and selection of participants:

This was a retrospective cohort study using population-based administrative databases from all hospital EDs in the province of Ontario that had implemented eCTAS for at least nine months

between January 2016 to December 2018. Following a three-month stabilization period facilitating ED triage nurses familiarity with and consistent use of eCTAS, we compared data for six months post-eCTAS implementation to the same six-month period the previous year (pre-implementation) to account for potential seasonal variation, patient volume and case-mix.

We included triage encounters of adult patients aged 18 years and older if they had one of the following 16 pre-specified high-volume, presenting complaints: altered level of consciousness; anxiety/situational crisis; chest pain (cardiac features); confusion; depression/suicidal/deliberate self-harm; extremity weakness/symptoms of cerebrovascular accident; fever; general weakness; head injury; hyperglycemia; palpitations; seizure; shortness of breath; substance misuse/intoxication; syncope; or vertigo. The 16 presenting complaints were *a priori* selected by a provincial steering committee to represent commonly encountered, high-volume conditions. We excluded data from urgent care centres, walk-in/ambulatory clinics, and EDs not open 24 hours per day.

Data sources

Data were obtained from province-wide health administrative databases through Ontario Health (Cancer Care Ontario), an agency of the provincial Government of Ontario responsible for improving healthcare services. Pre-eCTAS and post-eCTAS data were obtained from the Canadian Institute of Health Information National Ambulatory Care Reporting System (CIHI-NACRS). CIHI-NACRS contains anonymized, abstracted data on all ED visits in Ontario. Ontario has universal healthcare coverage for medically necessary care; therefore, these databases contain the

majority of healthcare utilization in the province. The research ethics board at Mount Sinai Hospital in Toronto, Ontario, Canada approved the study protocol.

Main exposure variable and outcomes

The main exposure variable was the CTAS system used which we characterize as pre-eCTAS (previous triage method) or post-eCTAS. Outcomes included hospital admission from the ED, the proportion of patients who left the ED without being seen by a healthcare provider (LWBS), and time from triage to physician initial assessment (PIA).

Statistical analysis

We used descriptive statistics to characterize the study population, an independent samples t-test to address differences in continuous variables, and chi-square statistics to address differences in categorical variables pre and post-eCTAS.

Patient age, sex, hospital ED type (low volume <30,000 annual ED visits; medium volume 30,000 to 49,999 annual ED visits; high volume 50,000 to 84,999 annual ED visits, and very high volume >85,000 annual ED visits), and previous triage process (paper-based or electronic) prior to the implementation of eCTAS may all influence the study outcomes. Therefore, to address the possible impact of eCTAS versus previous triage method on outcomes, we employed multivariable binary logistic regression models, with a generalized estimating equation (GEE) approach and an exchangeable 2-by-2 correlation matrix to account for clustering at the hospital level.<25> Model

fit was assessed by examining the Quasi-likelihood under Independence Model Criterion (QIC) statistic. The exchangeable working correlation was examined to assess the influence of clustering. The resulting correlation was 0.0072. Given the negligible effect of clustering (correlation close to 0 suggests minimal effect), we report the results from multivariable binary logistic regression models adjusting for patient age, sex, hospital volume and previous triage method without accounting for clustering. Variance inflation factors were examined to determine if model variables were colinear. All models were stratified by CTAS score to determine the effect of eCTAS implementation by triage category. Results are reported using adjusted odds ratios (OR) with 95% confidence intervals (CI).

Due to the right-skewed, non-parametric nature of time to PIA, we used quantile (50^{th} and 90^{th} percentile) regression models <26> adjusting for patient age, sex, hospital volume and previous triage method to assess the possible effect of eCTAS on wait times and report results using adjusted beta coefficients with 95% CIs. Models were stratified by CTAS score to explore the effect of eCTAS implementation by triage category. Patients who LWBS (n=10,269) were excluded from the analysis of hospital admission and time to PIA since they left the ED before the outcome of interest could occur. Data analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM SPSS Statistics, Armonk, New York).

We used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach which provides a structured and transparent framework to assess quality (high, moderate, low and very low) of the evidence. Observational studies such as the current one start as low quality

evidence and may be rated down for risk of bias, imprecision and inconsistency, and rated up for large effects.<27-29>

To compare our findings to the overall ED population in Ontario, we used NACRS data provided in the 2018/2019 CIHI report.<1>

Results

Data from 354,176 (173,363 pre-eCTAS, 180,813 post-eCTAS) triage encounters from 31 hospital EDs across Ontario informed the analysis. There were 6 (19.4%) low volume EDs, 8 (25.8%) medium volume EDs, 11 (35.5%) high volume EDs, and 6 (19.4%) very high volume EDs. Mean age (56.2 vs 56.4 years) and proportion of female patients (51.4% vs 51.4%) were similar pre and post-eCTAS implementation (Table 1).

There was a substantial change in the distribution of triage scores post-eCTAS, with fewer patients classified as CTAS 2 (47.1 vs 43.9%; Δ-3.2%; 95% CI: -3.5 to -2.9%; moderate quality) and CTAS 3 (45.1 vs 44.2%; Δ-0.9%; 95% CI: -1.3 to -0.6%; low quality), and more patients classified as CTAS 4 (5.2 vs 9.0%; Δ3.8%; 95% CI: 3.6 to 4.0%; moderate quality).

Table 1. Descriptive statistics for 354,176 triage encounters from 31 hospital emergency departments pre and post-eCTAS implementation.

Characteristic	Pre-eCTAS (n=173,363)	Post-eCTAS (n=180,813)	Total (N=354,176)
Mean (SD) age (years)	**56.2 (21.8)**	**56.4 (21.8)**	**56.3 (21.8)**
Age Group			
<65 years	104,589 (60.3%)	108,144 (59.8%)	212,733 (60.1%)
65-75 years	28,501 (16.4%)	30,477 (16.9%)	58,978 (16.6%)
>75 years	40,273 (23.2%)	42,192 (23.3%)	82,465 (23.3%)
Sex			
Female	89,022 (51.4%)	93,005 (51.4%)	182,027 (51.4%)
Male	84,341 (48.6%)	87,808 (48.6%)	172,149 (48.6%)
CTAS Score*			
1	3,854 (2.2%)	4,705 (2.6%)	8,559 (2.4%)
2	81,679 (47.1%)	79,405 (43.9%)	161,084 (45.5%)
3	78,199 (45.1%)	79,899 (44.2%)	158,098 (44.6%)
4	9,023 (5.2%)	16,301 (9.0%)	25,324 (7.2%)
5	367 (0.2%)	308 (0.2%)	675 (0.2%)
Hospital Volume			
Low	8,198 (4.7%)	8,716 (4.8%)	16,914 (4.8%)
Medium	28,077 (16.2%)	28,798 (15.9%)	56,875 (16.1%)
High	63,308 (36.5%)	65,999 (36.5%)	129,307 (36.5%)
Very High	57,477 (33.2%)	61,190 (33.8%)	118,667 (33.5%)
Academic	16,303 (9.4%)	16,110 (8.9%)	32,413 (9.2%)
Previous Triage Method			
Paper-based	69,136 (39.9%)	74,012 (40.9%)	143,148 (40.4%)
Electronic	104,227 (60.1%)	106,801 (59.1%)	211,028 (59.6%)

Where: SD = standard deviation; eCTAS = electronic Canadian Triage and Acuity Scale; CTAS = Canadian Triage and Acuity Scale.

*there were 241 triage encounters in the pre-eCTAS cohort and 195 triage encounters in the post-eCTAS cohort that were missing CTAS scores.

Table 2 displays a summary of findings for the outcomes of interest. Hospital admission adjusted for patient age, sex, hospital volume and previous triage method decreased post-eCTAS (OR: 0.98; 95% CI: 0.97 to 1.00; absolute difference of 4/1,000 to 0 fewer; low quality). If we applied the same 0.2% reduction to the 647,389 patients admitted across the province in 2018/19, this would suggest 1,295 fewer patients would be admitted from the ED each year.<1>

When the model was stratified by CTAS category, there were fewer CTAS 2 and more CTAS 3 and CTAS 4 patients admitted post-eCTAS, with moderate quality of evidence (Table 3). In terms of attribution of differences to eCTAS, evidence proved moderate quality for CTAS 2, CTAS 3 and CTAS 4, and low quality for CTAS 1 and CTAS 5.

LWBS increased post-eCTAS (OR: 1.07; 95% CI: 1.03 to 1.11 absolute difference of 1/1,000 to 3/1,000 more; low quality). Confidence intervals around the difference in LWBS for triage categories was wide and therefore it was not possible to ascertain if the effect differed across CTAS scores. Overall, 50^{th} and 90^{th} percentile PIA times were similar pre and post-eCTAS implementation (low to moderate quality). When stratified by CTAS category, there was moderate quality evidence to suggest CTAS 4 patients waited longer to be seen by a healthcare provider post-eCTAS (Table 4).

Table 2. Summary of findings of the effect of eCTAS implementation on outcomes.

Outcome № of participants	Relative effect (95% CI)	Anticipated absolute effects (95% CI)			Quality of the evidence	What happens
		Pre-eCTAS	Post-eCTAS	Difference		
Hospital Admission № of participants: 343,907	**OR 0.98** (0.97 to 1.00)	**26.2%**	**26.0%** (25.9 to 26.1)	**0.2% fewer** (0.4 fewer to 0 fewer)	⊕⊕◯◯ LOW [a] Due to imprecision	There may be little or no difference in hospital admission.
LWBS № of participants: 354,176	**OR 1.07** (1.03 to 1.11)	**2.8%**	**3.0%** (2.9 to 3.1)	**0.2% more** (0.1 more to 0.3 more)	⊕⊕◯◯ LOW [a] Due to imprecision	There may be little or no difference in LWBS.
PIA № of participants: 343,907	Median time was **65** minutes pre-eCTAS compared to **65** minutes post-eCTAS (-0.45; 95% CI: -1.02 to 0.13) 90th percentile was **200** minutes pre-eCTAS compared to **199** minutes post eCTAS (-0.47; 95% CI: -2.00 to 1.06)				⊕⊕◯◯ LOW [a] Due to imprecision	There may be little or no difference in wait times.

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

LWBS: Left without being seen; **PIA:** Physician initial assessment; **CI:** Confidence interval; **OR:** Odds ratio

GRADE Working Group grades of evidence
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

a. Imprecision of the overall effect

Table 3. The effect of eCTAS implementation on hospital admission, stratified by triage category.

Characteristic	Number of patients	Pre-eCTAS admitted	Number of patients	Post-eCTAS admitted	Adjusted* OR (95% CI)	p-value	Quality of evidence
Overall	**168,487**	**44,057 (26.2%)**	**175,420**	**45,568 (26.0%)**	**0.98 (0.97 to 1.00)**	**0.04**	⊕⊕◯◯ LOW[a]
CTAS Score#							
1	3,852	2,793 (72.5%)	4,701	3,434 (73.0%)	1.00 (0.91 to 1.11)	0.96	⊕⊕◯◯ LOW[a]
2	80,586	25,533 (31.7%)	78,343	23,834 (30.4%)	0.95 (0.93 to 0.97)	<0.001	⊕⊕◯◯ MODERATE[b]
3	75,134	14,897 (19.8%)	76,733	16,551 (21.6%)	1.10 (1.07 to 1.12)	<0.001	⊕⊕◯◯ MODERATE[b]
4	8,386	722 (8.6%)	15,208	1,663 (10.9%)	1.17 (1.06 to 1.28)	0.002	⊕⊕◯◯ MODERATE[b]
5	294	22 (7.5%)	262	31 (11.8%)	1.82 (0.97 to 3.40)	0.06	⊕⊕◯◯ LOW[a]

*adjusted for patient age, sex, hospital volume and previous triage method.

a=due to imprecision
b=due to large effects

there were 235 triage encounters in the pre-eCTAS cohort and 173 triage encounters in the post-eCTAS cohort that were missing CTAS scores.

Table 4. The effect of eCTAS implementation on time from triage to physician initial assessment, stratified by triage category.

Characteristic	Pre-eCTAS		Post-eCTAS		50th Percentile Coefficient* (95% CI)	Quality of evidence	90th Percentile Coefficient* (95% CI)	Quality of evidence
	50th PIA	90th PIA	50th PIA	90th PIA				
Overall	**65 min**	**200 min**	**65 min**	**199 min**	**-0.45 (-1.02 to 0.13)**	⊕⊕◯◯ LOW[a]	**-0.47 (-2.00 to 1.06)**	⊕⊕◯◯ LOW[a]
CTAS Score*								
1	7 min	40 min	9 min	45 min	1.64 (1.02 to 2.26)	⊕⊕◯◯ LOW[a]	3.68 (-0.09 to 7.27)	⊕⊕◯◯ LOW[a]
2	56 min	189 min	56 min	185 min	-0.65 (-1.37 to 0.08)	⊕⊕◯◯ LOW[a]	-4.00 (-6.26 to -1.75)	⊕⊕⊕◯ MODERATE[b]
3	79 min	214 min	76 min	213 min	-2.67 (-3.59 to -1.74)	⊕⊕◯◯ LOW[a]	-0.37 (-2.68 to 1.95)	⊕⊕◯◯ LOW[a]
4	75 min	194 min	81 min	210 min	4.56 (2.14 to 6.98)	⊕⊕⊕◯ MODERATE[b]	13.50 (7.74 to 19.26)	⊕⊕◯◯ LOW[a]
5	64 min	161 min	74 min	195 min	9.31 (-6.31 to 24.93)	⊕⊕◯◯ LOW[a]	32.45 (-2.39 to 66.57)	⊕⊕◯◯ LOW[a]

*adjusted for patient age, sex, hospital volume and previous triage method.

a=due to imprecision
b=due to large effects

Interpretation

We explored the possible effect of eCTAS implementation versus previous triage method on hospital admission, rates of LWBS, and time to PIA using data from 354,176 triage encounters from 31 EDs across the province of Ontario. Quality of evidence refers to our confidence that changes were causally related to eCTAS implementation. Overall, low quality evidence suggests the implementation of eCTAS may have resulted in minimal changes in ED metrics. There was a change in the distribution of triage scores post-eCTAS that is likely due to eCTAS itself, with patients being reclassified from higher (CTAS 2 and CTAS 3) to lower (CTAS 4) acuity scores after eCTAS implementation. These changes were associated with higher admission for CTAS 3 and CTAS 4 patients. The rate of LWBS increased post-eCTAS, while PIA remained similar pre and post-eCTAS.

Strengths and Limitations

Strengths of this study include the use of population-based data from 354,176 triage encounters from 31 EDs across Ontario. The EDs represent a mix of previous triage methods and documentation practices (electronic vs paper-based), ED types (rural, community and teaching), and ED patient volumes (low to very high). This is the first study to explore the possible effect of eCTAS implementation versus previous triage method on ED metrics of hospital admission, rate of LWBS, and time to PIA. This study has several limitations. As of February 2020, eCTAS has been implemented in 115 (>90%) EDs across the province. However, at the time of this study, only 31 EDs had implemented eCTAS for at least nine months (three-month stabilization period

and at least six months of triage data using eCTAS) required for this evaluation. Whether our findings are applicable to all hospital EDs that have now implemented eCTAS remains uncertain.

A provincial steering committee selected the 16 presenting complaints included in this study, hoping to represent commonly encountered, high-volume conditions. Many of the included presenting complaints are associated with higher hospital admission compared to the overall ED population. Overall, hospital admission rates in Ontario in 2018/19 were 10.7%, much lower than the 26.2% pre-eCTAS and 26.0% post-eCTAS.<1> Therefore, it is possible our results may not be generalizable to all presenting complaints. Given the study design, we were unable to account for unmeasured confounders or possible effect-modifiers. It may be possible the observed effects reported in this study are related to unknown hospital and system-level changes initiated around the same time as eCTAS was implemented, thus, the designation of low quality evidence for the three outcomes of primary interest.

Implications

LWBS and time to PIA are important ED quality-of-care metrics. Although the majority of patients who leave the ED without being seen have minor health concerns, there are some patients who may have serious health issues where a delay in treatment can result in adverse outcomes.<30> The rates of LWBS found in this study (2.8% pre-eCTAS and 3.0% post-eCTAS) were lower than the 3.5% LWBS rate reported for Ontario in 2018/19.<1> Again, this is likely a result of the more serious nature of presenting complaints included in this study.

The primary reason why patients leave the ED without being seen is “fed up with waiting” or “prolonged waiting time”, irrespective of the actual time spent waiting or their triage score.<30-33> Overall, we found no change in time from triage to PIA, except for CTAS 4 patients who waited an additional 4.5 minutes to be seen by a healthcare provider. Additional studies are required to more fully understand the patterns and consequences of LWBS, and how these may or may not be related to eCTAS implementation.

We documented a change in the distribution of triage scores, with patients being reclassified from higher (CTAS 2 and CTAS 3) to lower (CTAS 4) acuity scores after eCTAS implementation. A possible explanation for this reclassification is that eCTAS is appropriately triaging patients based on how safely they can wait to be seen based solely on their presenting complaint. Triage in general, and CTAS in particular, was not designed to be an indicator of resource intensity or physician workload, so while it may take an extended amount of time and resources to manage an 85 year old well-appearing woman with multiple comorbidities who presents to the ED with uncomplicated cellulitis, she may be appropriately triaged as a CTAS 4 who can safely wait to be seen. It is possible that eCTAS, as a more objective way of applying CTAS criteria, results in more objective CTAS score than triage by a nurse without this support tool.

Another explanation for the downward shift in triage scores post-eCTAS may be related to the use of clinical modifiers when triage decisions are being made. The eCTAS application requires the user to select a presenting complaint from a standardized list of 169 complaints and then displays a CTAS-based template with complaint-specific modifiers (e.g., vital signs, respiratory distress,

hemodynamic status, level of consciousness, pain score, bleeding disorder, and mechanism of injury). We previously found that use of complaint-specific modifiers was associated with increased triage consistency, particularly for non-specific presenting complaints such as shortness of breath, fever and general weakness. It is possible that nurses were less frequently applying modifiers post-eCTAS, and if so, patients may be under-triaged. Under-triage may contribute to delays in time-sensitive interventions and lead to potentially avoidable clinical deterioration and misdiagnosis.<34-38>

The redistribution of CTAS scores with eCTAS may possibly impact ED funding. A variety of models are used by hospitals and provincial governments to estimate the number of physician hours of coverage necessary to staff EDs.<13-16> In Ontario, approximately 85% of EDs with more than 27,500 annual visits are funded by a formula using ED patient volume and acuity, based on CTAS scores.<14,15> If the change in the distribution of triage scores (from higher to lower acuity) is generalizable to the entire ED population, this may affect ED physician funding results for sites using workload models. Increasingly, emergency medicine providers and leaders have expressed concern about the validity of workload models derived from ED visit volume and CTAS scores, considering triage scores do not consistently correlate with patient complexity or resource intensity. Future studies should examine the effect of eCTAS implementation on ED physician workload models.

Conclusions

In this retrospective cohort study using administrative data from 354,176 triage encounters from 31 EDs across Ontario, we found eCTAS implementation had little impact on hospital admission, LWBS and time to PIA. eCTAS is likely responsible for reclassification of patients from higher to lower acuity scores, resulting in higher admission rates for CTAS 3 and CTAS 4 patients. Whether or not this reclassification is appropriate remains uncertain.

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Declaration of Interest: At the time of the study, SS, TA, and NM were paid employees of Ontario Health (Cancer Care Ontario). HO is a paid advisor to the Ministry of Health of Ontario and in that capacity has provided leadership to the eCTAS project. SLM, KG, CT, LT, BB, AW, TA and GG state no conflict of interest and have received no payment in preparation of this manuscript.

Author Contributions: SLM, LT, BB, NM and GG conceived the study and designed the protocol. SLM, LT, and GG supervised the conduct of the study. SLM, SS, and TA managed the data, including quality control. SLM, KG, CT, LT and GG provided statistical advice and conducted the data analysis. BB and NM chaired the data oversight committee. KG, BB, HO, AW, TA, and GG provided clinical advice on study interpretation. SLM drafted the manuscript, and all authors contributed substantially to its revision. SLM takes responsibility for the paper as a whole.

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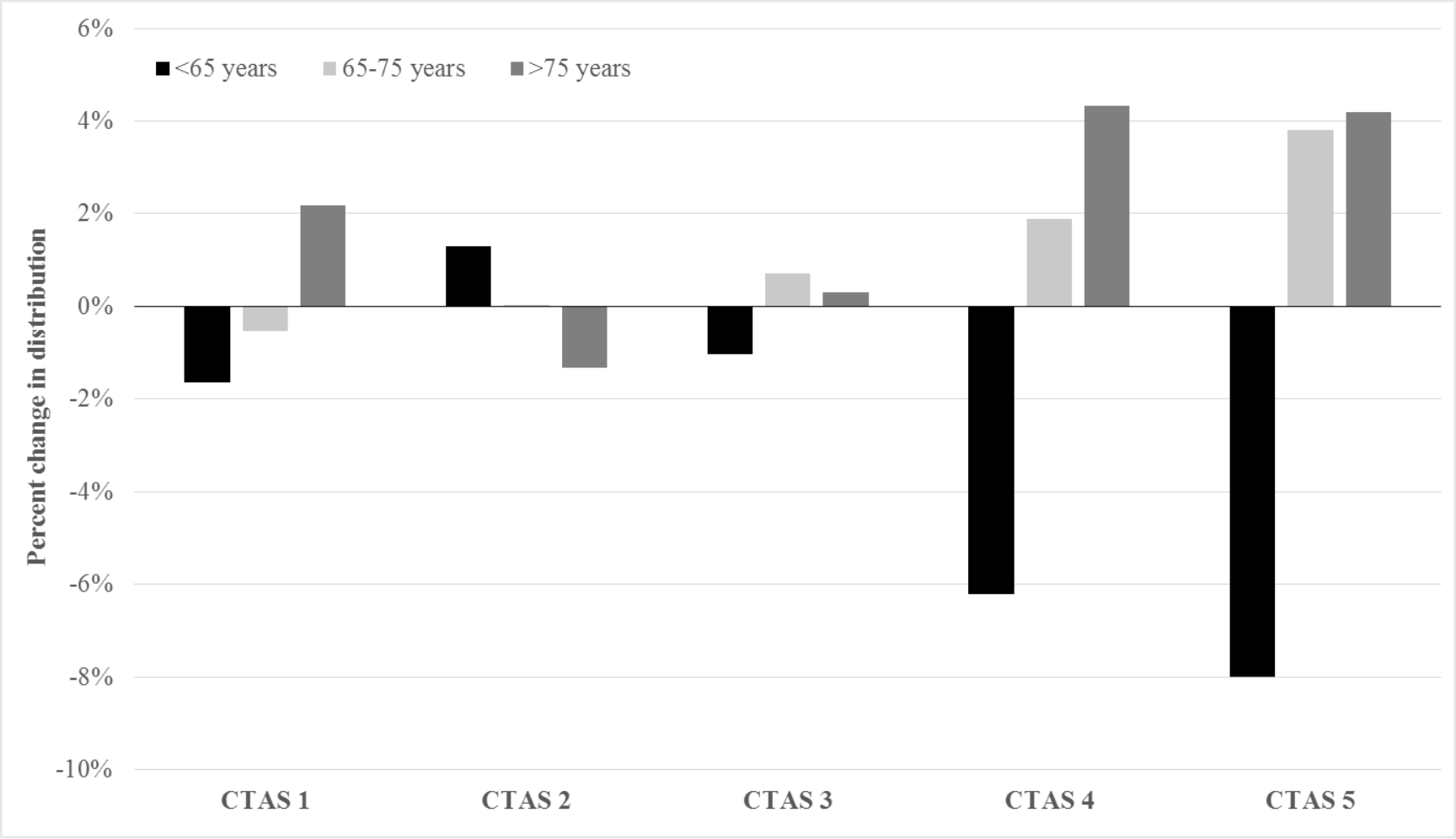
Supplementary Table 1. The effect of eCTAS implementation on left without being seen, stratified by triage category.

Characteristic	Number of patients	Pre-eCTAS LWBS	Number of patients	Post-eCTAS LWBS	Adjusted* OR (95% CI)	p-value
Overall	**173,363**	**4,876 (2.8%)**	**180,813**	**5,393 (3.0%)**	**1.07 (1.03 to 1.11)**	**0.001**
CTAS Score*						
1	3,854	2 (0.0%)	4,705	4 (0.1%)	1.55 (0.28 to 8.50)	0.62
2	81,679	1,093 (1.3%)	79,405	1,062 (1.3%)	1.00 (0.92 to 1.09)	0.93
3	78,199	3,065 (3.9%)	79,899	3,166 (4.0%)	1.03 (0.98 to 1.08)	0.30
4	9,023	637 (7.1%)	16,301	1,093 (6.7%)	1.02 (0.92 to 1.13)	0.68
5	367	73 (19.9%)	308	46 (14.9%)	0.67 (0.41 to 1.07)	0.09

*adjusted for patient age, sex, hospital volume and previous triage method.

there were 241 triage encounters in the pre-eCTAS cohort and 195 triage encounters in the post-eCTAS cohort that were missing CTAS scores.

Supplementary Figure 1. Percent change in the overall volume distribution pre and post-eCTAS implementation by age group and triage category.



CHAPTER 5: CONCLUSION

Summary of Findings

This dissertation describes findings from the provincial implementation of eCTAS, a real-time, electronic, decision-support tool, designed to standardize the application of national triage guidelines. In our prospective, observational study conducted in seven hospital EDs in Ontario, we found interrater agreement and triage accuracy were higher across all seven included EDs, and median triage time was similar after the implementation of eCTAS. Using the auditor's CTAS score as the reference, eCTAS significantly reduced the number of patients over-triaged over-triaged and under-triaged, and this was consistent across all participating sites.

In our second study, we used data from 363,214 (183,231 pre-eCTAS, 179,983 post-eCTAS) triage encounters from 35 EDs to evaluate the consistency of CTAS score distributions by a variety of presenting complaints pre and post-eCTAS implementation. We found that a standardized, electronic approach to performing triage assessments increased consistency in CTAS scores across many, but not all, high-volume presenting complaints. We also found the use of complaint-specific modifiers varied substantially between hospitals and presenting complaints. ED sites that were least consistent with the overall CTAS distribution had the lowest use of modifiers across all presenting complaints. Findings from this study may be useful to optimize the use of eCTAS in EDs, especially in those EDs that failed to show improvements in consistency and guide triage nurse education.

In our third study, we explored the possible effect of eCTAS implementation on hospital admission, the proportion of patients who left the ED before they were seen by a healthcare provider (LWBS), and the time from triage to physician initial assessment (PIA). Overall, we had low quality evidence using 354,176 triage encounters from 31 EDs to suggest the implementation of eCTAS resulted in minimal changes in ED metrics. There was a change in the distribution of triage scores post-eCTAS that was likely due to eCTAS itself, with patients being reclassified from higher (CTAS 2 and CTAS 3) to lower (CTAS 4) acuity scores after eCTAS implementation. These changes were associated with higher admission for CTAS 3 and CTAS 4 patients. Whether or not this reclassification is appropriate remains uncertain, but if the change in the distribution of triage scores (from higher to lower acuity) is generalizable to the entire ED population, this may impact ED physician funding.

Suggestions for Future Research

As of March 2020, eCTAS has been implemented in 115 (>90%) EDs across the province. Future research should include data from all hospital EDs that have now implemented eCTAS to determine if our consistency and ED metric findings are generalizable to all EDs in Ontario. Similarly, the 16 presenting complaints included in this research were selected by a provincial steering committee to represent commonly encountered, high-volume conditions that have a minimum allowable CTAS score (e.g., none of the included complaints should be assigned a CTAS score of 5). However, many of the included presenting complaints are associated with higher acuity and hospital admission compared to the overall ED population, so we remain uncertain if our findings are applicable to all presenting complaints and all hospital EDS in Ontario. Future

research should include all presenting complaints, or at least presenting complaints associated with lower acuity (e.g., CTAS 4 and CTAS 5) to ensure our findings are appropriate for the entire ED population.

eCTAS was designed as a real-time, clinical decision support tool to be used in the ED by triage personnel, not as a research application. Personal health information such as Ontario health insurance plan number (OHIP), full name, and date of birth are not mandatory fields to be collected and entered in eCTAS. When this information is available, it is relatively uncomplicated to link eCTAS data to other province-wide administrative databases such as the Canadian Institute of Health Information National Ambulatory Care Reporting System (CIHI-NACRS) to obtain patient-important outcomes that occurred after the ED visit, but when it is missing (OHIP is only available for approximately 40% of all triage encounters captured by eCTAS), data must be matched using probabilistic algorithms that have yet to be validated. Future research should address these issues and harness the full potential of this real-time database through more coordinated efforts with other administrative databases.

In EDs where eCTAS has been implemented, approximately 5-7% of triage encounters are not being captured by eCTAS. However, not all ED patients require a thorough and comprehensive triage. Patients who present with serious, life threatening illness or injury (e.g., cardiac arrest) can be quickly assessed and triaged based on their presenting complaint and general appearance. These patients are often a CTAS 1 and may not be entered into the eCTAS database. Additionally, there may be times when eCTAS is unavailable due to system downtime, eCTAS updates or

maintenance, so patients may be triaged using a different process (paper-based triage). These patients may not be captured by eCTAS, unless the triage nurse manually enters the data after the triage encounter. There may also be situations when the triage nurse simply does not use eCTAS to triage patients in the ED for other reasons currently unknown. Future research should attempt to elucidate barriers and facilitators to eCTAS compliance through semi-structured interviews and focus groups of triage personnel.

We found that the use of clinical modifiers varied substantially between hospitals and presenting complaints. ED sites that were least consistent with the overall CTAS distribution had the lowest use of modifiers across all presenting complaints. Although we can only speculate why some triage nurses did not enter clinical modifier data, it seems likely to be related to perceived process time, improper education or triage efficiency. Future research should address this and study if educational interventions such as regular audit and feedback and a targeted educational curriculum clarifying the importance of modifier selection would improve triage consistency and use of modifiers.

There may be future research opportunities to further develop the electronic decision-support triage process to more fluidly accommodate and amplify the tacit knowledge possessed by the nurse. It would be of interest to try to elucidate how eCTAS influences clinical assessment, triage decision making, workflow in the ED, and the perceived effect of eCTAS compared to previous triage methods by patients regarding the nurse interaction and communication during the triage

process. There may be human factors or structural changes that can be implemented within the eCTAS platform to enhance the triage process.

It would also be interesting to examine if there are presenting complaints or triage encounters when triage nurses are more likely to "override" the suggested eCTAS score. Further study focusing on user over-rides to determine whether they are related to specific complaints, populations, clinical impression, user bias or inconsistencies in CTAS would be useful to optimize eCTAS, triage education and guide future enhancements.

Finally, we found a change in the distribution of triage scores post-eCTAS that was likely due to eCTAS itself, with patients being reclassified from higher (CTAS 2 and CTAS 3) to lower (CTAS 4) acuity scores after eCTAS implementation. Whether or not this reclassification is appropriate remains uncertain, but if the change in the distribution of triage scores (from higher to lower acuity) is generalizable to the entire ED population, this may impact ED physician funding, as approximately 85% of EDs with more than 27,500 annual visits are funded by a formula using ED patient volume and acuity, based on CTAS scores. Future studies should examine the effect of eCTAS implementation on ED physician workload models compared to previous triage methods.

As emergency care continues to demand higher efficiency to manage increasing ED volumes and patient complexity, there is a need for a timely, accurate and reliable triage system to provide safe and optimal care. Future studies should continue to examine if eCTAS addresses these needs.