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

By SHELLEY L. MCLEOD, MSc, MSc, BSc

A Thesis

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in Partial Fulfillment of the Requirements for

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TITLE: 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 seven 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.
ACKNOWLEDGMENTS

This work would not have been possible without the contribution and support of many extraordinary people that I am privileged to call mentors, colleagues, friends and family. To my supervisor, Dr. Gordon Guyatt, your mentorship, guidance and continuous encouragement have been invaluable. You have taught me to think critically and choose my words carefully, advice that I will carry forward throughout my career. You miraculously always find time to answer my questions and provide feedback, regardless of your schedule. Many thanks to you and Maureen for welcoming Sheldon and I into your home for countless dinners, excellent conversations and the opportunity to sample more risotto recipes than I can remember.

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To my parents, Mary and Walter, I can absolutely say that I would not be the woman I am today if I didn’t have you both by my side. Thank you for taking my late-night phone calls when I am stressed and panicking, for being my biggest supporter in life, encouraging my pursuits, and guiding me in the right direction. Most of all, thank you for teaching me what the textbooks couldn’t.

Finally, this work is dedicated to the love of my life, my very best friend, my soulmate and husband, Dr. Sheldon Cheskes. You are my miraculous angel, my living breathing definition of love. Thank you for your patience and understanding over the past few months, and willingness to listen to me explain (over and over again) my research in far too much detail. Thank you for believing in me when I was doubtful, picking up the broken pieces along the way, and always, always encouraging and motivating me to move forward. A life-time is a long time, but it's far too short to spend with you.
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<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>ATS</td>
<td>Australasian Triage Scale</td>
</tr>
<tr>
<td>CCO</td>
<td>Cancer Care Ontario</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>CIHI</td>
<td>Canadian Institute of Health Information</td>
</tr>
<tr>
<td>CTAS</td>
<td>Canadian Triage and Acuity Scale</td>
</tr>
<tr>
<td>CTAS 1</td>
<td>Resuscitation</td>
</tr>
<tr>
<td>CTAS 2</td>
<td>Emergent</td>
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<tr>
<td>CTAS 3</td>
<td>Urgent</td>
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<tr>
<td>CTAS 4</td>
<td>Less urgent</td>
</tr>
<tr>
<td>CTAS 5</td>
<td>Non-urgent</td>
</tr>
<tr>
<td>CVA</td>
<td>Cerebrovascular Accident</td>
</tr>
<tr>
<td>eCTAS</td>
<td>electronic Canadian Triage and Acuity Scale</td>
</tr>
<tr>
<td>ED</td>
<td>Emergency Department</td>
</tr>
<tr>
<td>ESI</td>
<td>Emergency Severity Index</td>
</tr>
<tr>
<td>GEE</td>
<td>Generalized Estimating Equation</td>
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</table>
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
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>post-eCTAS</td>
<td>Prior to the Implementation of eCTAS</td>
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<tr>
<td>pre-eCTAS</td>
<td>After the Implementation of eCTAS</td>
</tr>
<tr>
<td>QIC</td>
<td>Quasi-likelihood under Independence Model Criterion</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
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<tr>
<td>Sec</td>
<td>Seconds</td>
</tr>
<tr>
<td>T</td>
<td>Teaching</td>
</tr>
<tr>
<td>Very-High Volume</td>
<td>&gt;85,000 annual ED visits</td>
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<tr>
<td>VHV</td>
<td>Very High Volume</td>
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<tr>
<td>Δ</td>
<td>Difference</td>
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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.\(^1\) 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).\(^8\) 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.\(^15\) Many provincial governments also use CTAS as an administrative metric to estimate patient care requirements, compare ED performance, and estimate ED physician staffing needs.\(^17\) However, despite its clinical and administrative importance, the process by which CTAS scores are derived is highly variable.\(^4\) 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.<sup>25</sup> 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.<sup>26</sup>

![Flow of eCTAS development.](image)

**Figure 1.** Flow of eCTAS development.

eCTAS is a real-time electronic decision-support tool, designed to standardize the application of national triage guidelines.<sup>26-27</sup> 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.<sup>28-30</sup> 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).
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.

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</table>
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
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CHAPTER 2: INTRERRATER RELIABILITY, ACCURACY AND TRIAGE TIME PRE AND POST-IMPLEMENTATION OF A REAL TIME ELECTRONIC TRIAGE DECISION-SUPPORT TOOL.

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\textsuperscript{8}Division of Emergency Medicine, The University of Western Ontario, London, Ontario, Canada
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. The eCTAS system was based on the concept of the eTRIAGE algorithm reported by Dong et al. 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

35
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

<table>
<thead>
<tr>
<th>Triage Nurse</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
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<td>18</td>
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<tr>
<td>TOTAL</td>
<td>2</td>
<td>157</td>
<td>336</td>
<td>226</td>
<td>31</td>
<td>752</td>
</tr>
</tbody>
</table>

Accuracy 0% 79% 75% 76% 58%
B. Post-eCTAS

<table>
<thead>
<tr>
<th>Triage Nurse</th>
<th>CTAS Auditor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>164</td>
<td></td>
<td>10</td>
<td></td>
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<td></td>
<td>175</td>
</tr>
<tr>
<td>3</td>
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<td>3</td>
<td></td>
<td>14</td>
<td></td>
<td>6</td>
<td>346</td>
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<tr>
<td>4</td>
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<td>1</td>
<td></td>
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<td>7</td>
<td></td>
<td>152</td>
</tr>
<tr>
<td>5</td>
<td>57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4168</td>
<td>341</td>
<td>155</td>
<td>71</td>
<td></td>
<td></td>
<td>739</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Hospital Type</th>
<th>Exact Modal Agreement (%)</th>
<th>Under Triaged (%)</th>
<th>Over Triaged (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Community</td>
<td>74.4</td>
<td>92.0</td>
<td>8.9</td>
</tr>
<tr>
<td>Academic</td>
<td>72.6</td>
<td>91.1</td>
<td>15.1</td>
</tr>
<tr>
<td>Community</td>
<td>76.7</td>
<td>92.5</td>
<td>12.3</td>
</tr>
<tr>
<td>Rural</td>
<td>72.8</td>
<td>96.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Rural</td>
<td>73.4</td>
<td>91.7</td>
<td>18.3</td>
</tr>
<tr>
<td>Large Community</td>
<td>82.5</td>
<td>94.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Large Community</td>
<td>71.8</td>
<td>91.7</td>
<td>15.5</td>
</tr>
<tr>
<td>Total</td>
<td><strong>75.4</strong></td>
<td><strong>92.7</strong></td>
<td><strong>12.6</strong></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Hospital Type</th>
<th>Unweighted Kappa (95% CI)</th>
<th>Linear Weighted Kappa (95% CI)</th>
<th>Quadratic Weighted Kappa (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Community</td>
<td>0.61 (0.47, 0.74)</td>
<td>0.88 (0.80, 0.96)</td>
<td>0.70 (0.60, 0.81)</td>
</tr>
<tr>
<td>Academic</td>
<td>0.60 (0.50, 0.71)</td>
<td>0.87 (0.81, 0.94)</td>
<td>0.69 (0.60, 0.78)</td>
</tr>
<tr>
<td>Community</td>
<td>0.64 (0.48, 0.79)</td>
<td>0.87 (0.78, 0.96)</td>
<td>0.71 (0.58, 0.84)</td>
</tr>
<tr>
<td>Rural</td>
<td>0.56 (0.42, 0.70)</td>
<td>0.94 (0.88, 0.99)</td>
<td>0.63 (0.51, 0.76)</td>
</tr>
<tr>
<td>Rural</td>
<td>0.57 (0.43, 0.70)</td>
<td>0.88 (0.81, 0.96)</td>
<td>0.62 (0.50, 0.74)</td>
</tr>
<tr>
<td>Large Community</td>
<td>0.74 (0.65, 0.83)</td>
<td>0.90 (0.83, 0.9)</td>
<td>0.80 (0.73, 0.87)</td>
</tr>
<tr>
<td>Large Community</td>
<td>0.55 (0.39, 0.72)</td>
<td>0.88 (0.79, 0.96)</td>
<td>0.62 (0.49, 0.76)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.63 (0.58, 0.68)</strong></td>
<td><strong>0.89 (0.86, 0.92)</strong></td>
<td><strong>0.71 (0.67, 0.74)</strong></td>
</tr>
</tbody>
</table>

Where: CI: confidence interval; Pre = pre-eCTAS implementation; Post = post-eCTAS implementation.
Table 4. Median triage time by hospital pre and post-eCTAS implementation.

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

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.

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

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.<sup>29</sup> 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.<sup>30,31</sup> 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 quadratic-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).<sup>19</sup> 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).<sup>32</sup> 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).<sup>29</sup>
In 2003, Grafstein et al., reported the interrater reliability of a computer-linked triage system using CTAS in real-time.<sup>33</sup> 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).<sup>33</sup>

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.<sup>24</sup> 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.<sup>25</sup>

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. <sup>34</sup>
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.
Acknowledgements: We would like to acknowledge the provincial eCTAS Steering Committee, triage nurses, ED staff and research assistants at all the participating hospital sites. Without their support, this study would not have been possible.

Declaration of Interest: The study was funded by the Ontario Ministry of Health. The funding agreement ensured the investigators maintained control over the study design, methods and interpretation of the results. JM, TA, NM, SS, and JG are paid employees of Cancer Care Ontario. HO is a paid advisor to the Ontario Ministry of Health and in that capacity has provided leadership to the eCTAS project. SLM, KG, MB, BHR, JD and BB state no conflict of interest and have received no payment in preparation of this manuscript.

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.
References


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 k 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 model 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 k 0.89 versus 0.63; quadratic-weighted k 0.93 versus 0.70). Median triage time was 312 seconds (n=3,968 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.

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.10 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).10 CTAS is similar to other standardized triage algorithms, including the Australasian Triage Scale12 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.15,16,17,19,20 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 tovalidate 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. The eCTAS system was based on the concept of the eTRIAGE algorithm reported by Dong et al. 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 (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 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
Reliability and Usability of eCTAS

“train the trainer” that includes a full teaching module to allow hospital trainers to share the updates. There is also a help module 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 κ<0.2 interpreted as poor agreement, κ=0.2 to 0.4 interpreted as fair agreement, κ=0.41 to 0.60 interpreted as moderate agreement, κ=0.61 to 0.80 interpreted as good agreement, and κ>0.80 interpreted as very good agreement.16,27 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 χ² 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

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B. Post-eCTAS

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categories post-eCTAS implementation. The use of eCTAS significantly reduced the number of patients under-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.

Inter-rater agreement pre- and post-eCTAS implementation by hospital is shown in Table 3. Across all sites, inter-rater 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 inter-rater 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 experience.
Table 3. Interrater agreement pre- and post-eCTAS implementation by hospital.

<table>
<thead>
<tr>
<th>Hospital Type</th>
<th>Unweighted ( k (95% \text{ CI}) )</th>
<th>Linear Weighted ( k (95% \text{ CI}) )</th>
<th>Quadratic Weighted ( k (95% \text{ CI}) )</th>
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<td>0.70 (0.60–0.81)</td>
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<td>Academic</td>
<td>0.60 (0.50–0.71)</td>
<td>0.87 (0.61–0.94)</td>
<td>0.69 (0.60–0.78)</td>
</tr>
<tr>
<td>Community</td>
<td>0.64 (0.48–0.79)</td>
<td>0.87 (0.78–0.96)</td>
<td>0.71 (0.58–0.84)</td>
</tr>
<tr>
<td>Rural</td>
<td>0.56 (0.42–0.70)</td>
<td>0.94 (0.86–0.99)</td>
<td>0.63 (0.51–0.76)</td>
</tr>
<tr>
<td>Large community</td>
<td>0.57 (0.43–0.70)</td>
<td>0.88 (0.61–0.95)</td>
<td>0.62 (0.50–0.76)</td>
</tr>
<tr>
<td>Large community</td>
<td>0.74 (0.65–0.83)</td>
<td>0.90 (0.83–0.9)</td>
<td>0.80 (0.73–0.87)</td>
</tr>
<tr>
<td>Total</td>
<td>0.63 (0.58–0.68)</td>
<td>0.89 (0.86–0.92)</td>
<td>0.71 (0.67–0.74)</td>
</tr>
</tbody>
</table>

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.26 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 \( k \) statistics. When measurement scales that are ordinal are considered, such as a 5-level triage scale, some...
Table 5. Median triage time by triage process pre- and post-eCTAS implementation.

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

Individuals 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 level 5 and a second observer triaging the same patient as a CTAS level 2 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.0,31 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 al32 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 al33 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 al34 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 al35 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 al36 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 al37 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.\textsuperscript{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 (i.e., impression of higher acuity). Assigning a lower acuity score than CTAS recommends is not permitted.

In this study, there was marked improvement in triage accuracy across all 7 sites after eCTAS implementation (aggregate unweighted $\kappa$ 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.\textsuperscript{2,11} 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.

The authors acknowledge the provincial eCTAS Steering Committee, triage nurses, ED staff, and research assistants at all the participating hospital sites. Without their support, this study would not have been possible.

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Author contributions: SLM, NM, HO, MB, BHR, JD, and BB conceived the study and designed the protocol. HO and JS 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.

All authors attest to meeting the four ICME\textsuperscript{e}ICME.org\textsuperscript{e}\textsuperscript{e}\textsuperscript{e} authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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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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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. 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).

CTAS is similar to other triage algorithms including the Australasian Triage Scale (ATS) and the Manchester Triage Scale (MTS), which categorize patients based on perceived clinical urgency, but differs from other triage scales such as the Emergency Severity Index (ESI), 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.

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. 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.
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.\textsuperscript{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.\textsuperscript{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.

<table>
<thead>
<tr>
<th>CTAS Distribution (%)</th>
<th>CTAS 1</th>
<th>CTAS 2</th>
<th>CTAS 3</th>
<th>CTAS 4</th>
<th>CTAS 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OVERALL pre-eCTAS</strong></td>
<td>3.3%</td>
<td>41.4%</td>
<td>49.3%</td>
<td>5.8%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Individual ED (HV12) pre-eCTAS</strong></td>
<td>2.9%</td>
<td>51.7%</td>
<td>43.1%</td>
<td>2.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td><strong>Absolute Delta</strong></td>
<td>0.4</td>
<td>10.3</td>
<td>6.2</td>
<td>3.7</td>
<td>0</td>
</tr>
</tbody>
</table>

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.\textsuperscript{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.

<table>
<thead>
<tr>
<th>Presenting Complaint</th>
<th>Pre-eCTAS</th>
<th>Post-eCTAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean Age</td>
</tr>
<tr>
<td>Altered Level of Consciousness</td>
<td>4,289</td>
<td>64.0</td>
</tr>
<tr>
<td>Anxiety/Situational Crisis</td>
<td>9,212</td>
<td>38.0</td>
</tr>
<tr>
<td>Chest Pain (Cardiac Features)</td>
<td>35,012</td>
<td>55.9</td>
</tr>
<tr>
<td>Confusion</td>
<td>3,361</td>
<td>73.3</td>
</tr>
<tr>
<td>Depression/Suicidal/Deliberate Self Harm</td>
<td>11,108</td>
<td>34.5</td>
</tr>
<tr>
<td>Extremity Weakness/Symptoms of CVA</td>
<td>5,356</td>
<td>68.8</td>
</tr>
<tr>
<td>Fever</td>
<td>10,642</td>
<td>48.1</td>
</tr>
<tr>
<td>General Weakness</td>
<td>17,409</td>
<td>68.5</td>
</tr>
<tr>
<td>Head Injury</td>
<td>13,282</td>
<td>51.8</td>
</tr>
<tr>
<td>Hyperglycemia</td>
<td>1,856</td>
<td>55.6</td>
</tr>
<tr>
<td>Palpitations/Irregular Heartbeat</td>
<td>8,708</td>
<td>57.4</td>
</tr>
<tr>
<td>Seizure</td>
<td>4,573</td>
<td>42.6</td>
</tr>
<tr>
<td>Shortness of Breath</td>
<td>30,855</td>
<td>62.0</td>
</tr>
<tr>
<td>Substance Misuse/Intoxication</td>
<td>6,393</td>
<td>38.8</td>
</tr>
<tr>
<td>Syncope/Pre-syncope</td>
<td>9,171</td>
<td>57.6</td>
</tr>
<tr>
<td>Vertigo</td>
<td>12,004</td>
<td>57.9</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>183,231</strong></td>
<td><strong>55.4</strong></td>
</tr>
</tbody>
</table>

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.”

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

*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.

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

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.

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

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. 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. 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. 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. 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.

Acknowledgements: We would like to acknowledge the provincial eCTAS Steering Committee, and research staff at Ontario Health (Cancer Care Ontario). Without their support, this study would not have been possible.
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.

Publication Disclaimer: Parts of this material are based on data and information provided by Ontario Health (Cancer Care Ontario), and includes data received by Ontario Health (Cancer Care Ontario) from the Canadian Institute for Health Information (CIHI). The opinions, reviews, view and conclusions reported in this publication are those of the authors and do not necessarily reflect those of Ontario Health (Cancer Care Ontario) or CIHI. No endorsement by Ontario Health (Cancer Care Ontario) or CIHI is intended or should be inferred.
References


Appendix

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

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

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.”

<table>
<thead>
<tr>
<th>CTAS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-eCTAS (n=9,212)</td>
<td>20 (0.2%)</td>
<td>1,586 (17.2%)</td>
<td>5,867 (63.7%)</td>
<td>1,569 (17.0%)</td>
<td>120 (1.3%)</td>
</tr>
<tr>
<td>Post-eCTAS (n=8,578)</td>
<td>3 (0.0%)</td>
<td>997 (11.6%)</td>
<td>5,333 (62.2%)</td>
<td>2,245 (26.2%)</td>
<td>0.0 (0%)</td>
</tr>
</tbody>
</table>

**Delta 95% CI**

- `Pre-eCTAS`  
  - 1: -0.2 (-0.3 to 0)  
  - 2: -5.6 (-6.6 to -4.6)  
  - 3: -1.5 (-2.9 to 0.1)  
  - 4: 9.2 (7.9 to 10.3)  
  - 5: -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.”

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

*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.”

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

CTAS Distribution (%)

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.”

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

*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.”

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

*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.”

<table>
<thead>
<tr>
<th>CTAS</th>
<th>CTAS Distribution (%)</th>
<th>Pre-eCTAS (n=10,642)</th>
<th>Post-eCTAS (n=9,553)</th>
<th>Delta 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 (0.5%)</td>
<td>2 (37.3%)</td>
<td>3 (52.9%)</td>
</tr>
<tr>
<td>Pre-eCTAS</td>
<td></td>
<td>51</td>
<td>3,967</td>
<td>5,626</td>
</tr>
<tr>
<td>Post-eCTAS</td>
<td></td>
<td>59</td>
<td>3,275</td>
<td>5,299</td>
</tr>
</tbody>
</table>

*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.”

![Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint “General Weakness.”](image)

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

*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.”

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

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.”

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

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.”

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

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.”

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

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.”

<table>
<thead>
<tr>
<th>CTAS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-eCTAS (n=6,393)</td>
<td>63 (1.0%)</td>
<td>1,914 (29.9%)</td>
<td>3,820 (59.7%)</td>
<td>523 (8.2%)</td>
<td>49 (0.8%)</td>
</tr>
<tr>
<td>Post-eCTAS (n=5,966)</td>
<td>60 (1.0%)</td>
<td>1,484 (24.9%)</td>
<td>3,307 (55.4%)</td>
<td>1,115 (18.7%)</td>
<td>0 (0.0%)</td>
</tr>
</tbody>
</table>

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

CTAS Distribution (%)  

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-syncpe.”

<table>
<thead>
<tr>
<th>CTAS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-eCTAS (n=9,171)</td>
<td>82 (0.9%)</td>
<td>4,509 (49.2%)</td>
<td>4,363 (47.6%)</td>
<td>212 (2.3%)</td>
<td>5 (0.0%)</td>
</tr>
<tr>
<td>Post-eCTAS (n=9,294)</td>
<td>52 (0.6%)</td>
<td>3,109 (33.4%)</td>
<td>4,979 (53.6%)</td>
<td>1,154 (12.4%)</td>
<td>0 (0.0%)</td>
</tr>
</tbody>
</table>

**Delta 95% CI**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-eCTAS (n=9,171)</td>
<td>-0.3</td>
<td>(-0.6 to -0.1)</td>
<td>-15.7</td>
<td>(-17.1 to -14.3)</td>
<td>6.0</td>
</tr>
</tbody>
</table>

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.”

![Distribution of CTAS scores pre and post implementation of eCTAS by presenting complaint “Vertigo.”](image)

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

*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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Influence of eCTAS on ED metrics

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.<ref> 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.
Influence of eCTAS on ED metrics

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.)
Influence of eCTAS on ED metrics

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 (50th and 90th percentile) regression models 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...
Influence of eCTAS on ED metrics

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.

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

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, 50th and 90th 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.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>№ of participants</th>
<th>Relative effect (95% CI)</th>
<th>Anticipated absolute effects (95% CI)</th>
<th>Quality of the evidence</th>
<th>What happens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Admission</td>
<td>343,907</td>
<td>OR 0.98 (0.97 to 1.00)</td>
<td>26.2% (25.9 to 26.1)</td>
<td>✖️✖️◯◯ LOW a</td>
<td>Due to imprecision There may be little or no difference in hospital admission.</td>
</tr>
<tr>
<td>LWBS</td>
<td>354,176</td>
<td>OR 1.07 (1.03 to 1.11)</td>
<td>2.8% (2.9 to 3.1)</td>
<td>✖️✖️◯◯ LOW a</td>
<td>Due to imprecision There may be little or no difference in LWBS.</td>
</tr>
<tr>
<td>PIA</td>
<td>343,907</td>
<td>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)</td>
<td>✖️✖️◯◯ LOW a</td>
<td>Due to imprecision There may be little or no difference in wait times.</td>
<td></td>
</tr>
</tbody>
</table>

*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.

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

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

<sup>a</sup>=due to imprecision

<sup>b</sup>=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.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-eCTAS 50th PIA</th>
<th>Post-eCTAS 50th PIA</th>
<th>50th Percentile Coefficient* (95% CI)</th>
<th>Quality of evidence</th>
<th>Post-eCTAS 90th PIA</th>
<th>90th Percentile Coefficient* (95% CI)</th>
<th>Quality of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>65 min</td>
<td>65 min</td>
<td>-0.45 (-1.02 to 0.13)</td>
<td>☮☮☯☯ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
<td>199 min</td>
<td>-0.47 (-2.00 to 1.06)</td>
<td>☮☮☯☯ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>CTAS Score*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7 min</td>
<td>9 min</td>
<td>1.64 (1.02 to 2.26)</td>
<td>☮☮☮☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40 min</td>
<td>3.68 (-0.09 to 7.27)</td>
<td>☮籥☯☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>56 min</td>
<td>56 min</td>
<td>-0.65 (-1.37 to 0.08)</td>
<td>☮籥☺☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
<td>189 min</td>
<td>-4.00 (-6.26 to -1.75)</td>
<td>☮籥☻☺ MODERATE&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>79 min</td>
<td>76 min</td>
<td>-2.67 (-3.59 to -1.74)</td>
<td>☮籥☺☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
<td>214 min</td>
<td>-0.37 (-2.68 to 1.95)</td>
<td>☮籥☺☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>75 min</td>
<td>81 min</td>
<td>4.56 (2.14 to 6.98)</td>
<td>☮籥☮☺ MODERATE&lt;sup&gt;b&lt;/sup&gt;</td>
<td>194 min</td>
<td>13.50 (7.74 to 19.26)</td>
<td>☮籥☺☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>64 min</td>
<td>74 min</td>
<td>9.31 (-6.31 to 24.93)</td>
<td>☮籥☺☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
<td>161 min</td>
<td>32.45 (-2.39 to 66.57)</td>
<td>☮籥☺☺ LOW&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

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

<sup>a</sup>=due to imprecision

<sup>b</sup>=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.
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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. 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.
Acknowledgements: We would like to acknowledge the provincial eCTAS Steering Committee, and research staff at CCO. Without their support, this study would not have been possible.

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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References


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

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

*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
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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
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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.