Acute Care Enhanced Surveillance:

ACES User Manual

Knowledge Management

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KFL&A Public Health

Working together for better health

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Acronyms

ACES	Acute Care Enhanced Surveillance (system)
CDC	(US) Centers for Disease Control and Prevention
CIHI	Canadian Institute for Health Information
CoCo	Complaint Coder
CTAS	Canadian Triage Acuity Score
CUSUM	Cumulative Sum
DAD	Discharge Abstract Database
EARS	Early Aberration Reporting System
ED	emergency department
EDSS	Emergency Department Surveillance System
FRI	febrile respiratory illness
FSA	forward sortation area (first 3 characters of Canadian postal codes)
HIRA	Hazard Identification Risk Assessment
HPPA	Health Protection and Promotion Act
ICD-10	International statistical classification of diseases and related health problems
ILI	influenza-like illness
KFLA	Kingston, Frontenac and Lennox & Addington (region)
KFLAPH	Kingston, Frontenac and Lennox & Addington Public Health
LCL	lower control limit
LHIN	local health integration network
ME	maximum entropy
MOH	(Ontario) Ministry of Health, previously the MOHLTC (Ministry of Health and Long-Term Care)
MRDx	most responsible diagnosis
NACRS	National Ambulatory Care Reporting System
NB	Naive Bayes
NLP	natural language processing
PHAC	Public Health Agency of Canada
PHU	public health unit; local public health agency
RODS	Real-time Outbreak and Disease Surveillance
SARS	severe acute respiratory syndrome
UCL	upper control limit

SECTION 1: OVERVIEW OF THE ACES SYSTEM

Acute Care Enhanced Surveillance (ACES) provides real-time epidemiological surveillance for Ontario. ACES monitors emergency department records for more than 95% of Ontario's acute care hospitals[1] and nearly 80% of inpatient admissions records[2]. Records are monitored as the patients are being treated, enabling real-time situational awareness for disease outbreak and other potential health risks. Hospital visits are monitored with a sliding scale of specificity, from a province-wide assessment to our smallest level of geography, the forward sortation area (FSA, first three characters of Canadian postal codes). The temporal and spatial capabilities built into ACES enable public health to be better informed on the health of the community which, in turn, can improve public health protection and prevention initiatives.

This manual has been prepared to familiarize users with ACES and includes the following information:

SECTION 2 introduces ACES and its capabilities—includes an overview of practical applications of ACES in public health and emergency management.

SECTION 2 provides scientific background for the methods and technology used in ACES—includes an historical overview and describes relevant scientific concepts and technical terminology.

SECTION 3 is a practical user guide for the ACES interface—includes descriptions of functionalities, such as mapping and alerting protocols.

SECTION 4 includes tables of relevant information such as a a list of current ACES syndromes.

1.1. Introduction to ACES

The global nature and fast pace of the contemporary health care environment present formidable challenges to traditional methods of health surveillance, such as surveys, reporting of priority diseases from sentinel primary care practices, and retrospective analysis of hospital charts. Traditional surveillance methods were put to the test in late 2003 with the pandemic threat of Severe Acute Respiratory Syndrome (SARS). Reports from this period, including the Naylor Report (1) and the Campbell Commission (2), confirmed that Ontario's emergency preparedness needed updating, especially improved health surveillance.

Concurrent to global health events, developments in machine learning were making large-scale automated data analyses possible, and advances in geographic information systems (GIS) were enabling geospatial visualizations of data at the global, national, and regional scale. At this confluence of public health need and technological advancement was the development of real-time surveillance methods capable of providing faster monitoring for a growing list of health conditions. These include influenza outbreaks, the health effects of extreme weather events, and clusters of health effects related to illicit drug use. Syndromic surveillance developed from these needs and technological developments: **syndromic surveillance** is a group of surveillance methods that monitor health-seeking data, available in real time (immediately) or near-real time (within 1 to 24 hours, for example), and applying statistical methods to identify abnormal activity that may indicate an outbreak or other public health concern**.** The data used for syndromic surveillance include web searches for keywords related to symptoms or relief-seeking, social media postings (e.g., Twitter), calls to telephone nurse advice lines (e.g., Telehealth Ontario), or patient triage registration records from emergency departments. Early identification can enable early intervention.

ACES was started in 2004 as a two-year pilot project called the Emergency Department Syndromic Surveillance (EDSS) system to assess the efficacy of monitoring triage registration records from two Kingston EDs. EDSS was both developed and funded by a collaboration between Kingston, Frontenac, and Lennox & Addington Public Health (KFLAPH), the Public Health Division of the Ministry of Health (MOH), Queen's University, the Public Health Agency of Canada (PHAC), Kingston General Hospital and Hotel Dieu Hospital. EDSS was based on an open-source software package from the University of Pittsburgh's Real-time Outbreak and Disease Surveillance (RODS) system.

The RODS system was modified for the needs of an Ontario-based population, such as the customized geospatial mapping and the optimization of alerts and syndrome classification. The EDSS system collated specific data elements from triage records such as chief complaint as free text, date and time of visit, hospital name, patient age, patient sex, and patient postal code (to 5 characters). Classifying algorithms derived from machine learning applications were used to categorize each ED visit into pre-defined and medically significant syndromes according to the words, parts of words, and phrases found in the chief complaints. Eight syndromes were defined for the EDSS, including gastrointestinal (to capture all potentially infectious gastrointestinal conditions) and fever/influenza-like-illness (ILI)

[1] 157 facilities as of March 2020. There are less than 5 hospital facilities with the technical ability to share data with ACES in Ontario; negotiations are ongoing to onboard these remaining facilities.

[2] 131 facilities as of March 2020. This number is increasing as hospitals that share ED records update data transmissions to include inpatient admissions.

(to capture all potentially infectious ILI conditions). Since its inception in 2004, ACES has grown from 2 EDs in Kingston, to more than 150 acute care hospitals, providing more than 97% coverage of the province.

Syndrome: pre-defined groupings of symptoms or health indicators that may indicate a clinical diagnosis or health outcome.

In early 2015, the EDSS was renamed Acute Care Enhanced Surveillance (ACES), to reflect the increasing scope of the acute care partners participating in the system across Ontario, as well as the system's enhanced capabilities. The system continues to be maintained by KFLAPH with funding from the MOH. ACES, like the EDSS, continues to allow users to (1) monitor acute care hospital volume, admissions, and surge capacity to help prepare for high volumes of patients, particularly in the event of an influenza pandemic, (2) monitor trends and/or changes in the incidence of endemic disease, and (3) detect new or emerging public health threats. The additional acute care coverage of ACES allows for unprecedented situational awareness both within specific public health jurisdictions and across Ontario. The enhanced capabilities of ACES include improved and more interactive epidemiological assessment tools, such as intuitive graphing, built-in calculations of standard deviations and moving averages, and monitoring capabilities that reflect real-time values. Furthermore, ACES gives users access to ED visits and/or admission volumes based on either hospital location or patient address.

The expansion of ACES to nearly full provincial coverage has afforded the creation of several information products that can be accessed by health professionals without access to the ACES interface. The ILI Mapper (*mapper.kflaphi.ca/ilimapper/*) provides surveillance of influenza activity by public health agency throughout the flu season and the Ontario Acute Care Surge Monitor (*kflaph.ca/ ontario-acute-care-surge-monitor*) provides estimates of patient volumes at all participating hospitals. ACES is used by public health agency epidemiologists and emergency management staff, as well as health professionals with roles in provincial and municipal government. The various ways that ACES has improved health surveillance capacity in Ontario is outlined in the following sections.

1.2. ACES for Public Health and Emergency Management

The flexibility, adaptability, monitoring, and analysis capabilities of ACES enable situational awareness for a variety of common, emerging, or unexpected public health issues. ACES' syndromic surveillance capabilities are useful in a variety of situations, including (but not limited to):

- routine monitoring of seasonal influenza,
- reportable disease detection,
- public health emergencies,
- surveillance of mass gatherings,
- public health emergencies (such as fires and extreme weather events),
- monitoring asthma,
- surveillance after drug policy changes, and
- mental health surveillance.

Six of these are discussed in the following sections, i.e., influenza, reportable disease detection, mass gatherings, emergencies and extreme weather, surveillance after drug policy changes, and asthma.

1.2.1. *Influenza Surveillance*

ACES provides invaluable information for health care services throughout Ontario for seasonal influenza via the ILI Mapper *(mapper.kflaphi.ca/ilimapper/).* The mapper uses aggregate ACES date to display provincial respiratory and influenza activity in both map and graph forms. It is open access so all health professionals (or any other interested party) in the province can use it to track influenza activity and other respiratory illnesses throughout the flu season. The Mapper includes information about surge capacity, virus progression, and infection rates to help health care service planning and implementation of alternative strategies for protecting the public. Additional provincial and federal health agency resources are provided, including monthly counts of influenza-related ICD-10 codes provided by the MOH from the NACRS and DAD[3] databases.

The value of ACES to monitor health outcomes during an influenza pandemic was demonstrated during the 2009 H1N1 epidemic. Influenza viruses circulate each year but the H1N1 pandemic had a higher than normal infection rate and older adults were not infected at disproportionate rates as is normally expected—in other words, H1N1 was infecting otherwise healthy and young people at alarming rates. The first cases of H1N1 in Ontario were confirmed in late April 2009. When a second wave of outbreak occurred in the fall of 2009, ACES monitored the outbreak in real-time within the region served by KFLAPH. ACES' respiratory and fever/ILI syndromes were able to detect and describe the increase in ED visits for respiratory complaints leading up to and during the H1N1 outbreak. Surveillance maps generated using ACES data visually identified regions with high numbers of flu-related ED visits. Additionally, the trends displayed in the ACES-generated epi curves[4] indicated that there would likely be ongoing increasing numbers of patients visiting local EDs, threatening an overload of each

[3] NACRS (National Ambulatory Care Reporting System) and DAD (Discharge Abstract Database) are ED and inpatient admissions databases maintained by the Canadian Institute for Health Information (CIHI). All Ontario acute care facilities are required to submit data to these databases and are generally available with a 3-month lag time.

[4] Epi curve: a visual display of cases associated with illness (or syndrome). *cdc.gov/training/QuickLearns/createepi/1.html*

ED's capacity. Based on this information, assessment centres were established to relieve the pressure on the EDs, resulting in a decline in ED visits over the following two weeks. ACES helped detect, describe, and track the outbreak earlier, and it provided essential information for health professionals regarding current and expected patient volumes to enable a concerted health system response.

1.2.2. *Reportable disease detection*

Through the Health Protection and Promotion Act (HPPA[5]), public health agencies in Ontario are required to track over 50 communicable diseases[6]. The testing laboratory typically notifies the MOH of a positive test for a reportable disease and public health notifies the patient of treatment options and what to expect during their illness and/or treatment. Reportable diseases can be monitored using ACES in several ways: specific syndromes related to the reportable disease can be monitored, key words from the chief complaints[7] included in the patient triage records can be used to identify potential cases, and/or epidemiologists can examine individual ED records in ACES and flag instances that require further investigation by a public health nurse, infection control practitioner, or health inspector. ACES data help public health agencies meet their HPPA obligations and enable quick patient isolation (if necessary) and education of the afflicted patient to mitigate the potential spread of the disease.

1.2.3. *Mass Gatherings*

2010 G8 and G20 Summit

Mass gathering events generate significant public health risks and require appropriate preparations before the event, as well as sufficient surveillance during the event to attenuate potential health emergencies. From June 25th to 30th, 2010, the G8 and G20 Summits were held in Huntsville, ON, and Toronto, ON, respectively. A Hazard Identification Risk Assessment (HIRA) was prepared prior to the meetings that identified several potential risks including infectious and contagious diseases, food related hazards, environmental and/or severe weather emergencies, and injury and/or health and safety hazards.

ACES was used as a health surveillance tool during the G8 and G20 Summits to monitor syndromes representative of the identified risks. ACES provided hourly reports from June 17th through June 30th, monitoring ED patient volumes and priority syndromes. Throughout this time, three indicators were higher than expected: (1) total hospital admissions, (2) fever/ILI ED visits, and (3) dermatological infectious ED visits. These values were not significant or sustained and ultimately proved to not be indicative of a public health outbreak or incident. Moreover, the use of ACES for these events enabled simplified real-time surveillance and enhanced situational awareness for emergency management, as well as practical experience to guide future use of ACES during planned mass gatherings.

2015 Games & Parapan Am Games

In the summer of 2015, Ontario's Greater Golden Horseshoe area hosted the Pan Am/Parapan Am Games. The event included an estimated 10,000 athletes and 250,000 visitors. In preparation for the Games, a provincial Surveillance Work Group was convened that recommended ACES for health surveillance for the event. ACES coverage was extended to all acute care facilities throughout all regions affected by the Games. Fortunately, there were no adverse health events during the Games. The surveillance capacity of ACES was greatly enhanced in preparation for the Games in several ways:

1. public health professionals (e.g., epidemiologists, medical officers, public health nurses) were trained in the use of ACES;
2. the ACES interface was enhanced with improved technological capacity for multiple users; and
3. the situational awareness tool, PHIMS, was developed to enable advanced map-based visualization of aggregate ACES data in concert with meteorological, administrative, and demographic data.

1.2.4. *Emergencies and Extreme Weather*

Kingston Fire

On December 17th, 2013, a large fire broke out in a construction site near downtown Kingston, ON. The size of the fire and the wind conditions at the time led to concerns regarding the spread of fire to nearby buildings and health risks associated with exposure to smoke. KFLAPH started monitoring ED visits and admissions with ACES upon notification of the fire, specifically for syndromes associated with respiratory ailments (e.g., asthma, smoke inhalation, carbon monoxide exposure). Although no significant increases were detected, ACES helped emergency management to quickly assess the extent of the public health threat and inform hospitals of the potential patient volumes. ACES improved the overall situational awareness and preparation throughout the duration of the emergency. PHIMS was also used for enhanced situational awareness during the fire to assess wind patterns and air quality. ACES and PHIMS enabled public health to determine the geographic locations in Kingston that were at the highest risk for exposure to the effects of the fire, including determining the location of the most vulnerable individuals who should be given special consideration during evacuation efforts.

Midland Tornado

On June 23rd, 2010, a F2 Tornado hit Midland, ON. Winds in the area reached 180-240 km/h as the tornado cut a strip through the centre of the town, causing severe damage and leading the town to declare a state of emergency. In the minutes after the

[5] *ontario.ca/laws/statute/90h07*

[6] See list of reportable diseases at *ontario.ca/laws/regulation/910559*

[7] Chief Complaint: words and phrases included in a patient's triage registration to describe the main reasons (symptoms) for the ED visit.

tornado struck, ACES was used to monitor real time ED visits related to the tornado at the local hospital—visits for trauma were monitored to assess the extent of the injuries caused by the tornado and the potential surge in ED volume. ACES was invaluable to providing situational awareness during this emergency.

1.2.5. *Surveillance After Drug Policy Changes*

Methadone

Methadone is a synthetic opioid used in the maintenance treatment of patients who are addicted to opioids, such as heroin and morphine. On June 26th, 2014, the delivery of methadone maintenance therapy was changed in Ontario: the program began a transition from prescribing a compounded methadone solution to a more concentrated formulation of an oral solution of methadone. There was concern that this change may lead to dosing errors and accidental overdose. On July 17, 2014, KFLAPH initiated a surveillance program using ACES to assess recent ED visits for accidental or intentional opiate overdose. An increase in ED admissions might have indicated a negative effect of the new program. The pre-existing syndrome created to capture opiate-related ED visits was modified to monitor methadone-specific ED visits and admissions. Public health professionals could conclude that methadone overdose numbers were stable over the weeks before and after the initiation of the new program. ACES continues to provide on-going monitoring of methadone-related ED visits.

1.2.6. *Asthma*

More than 10% of Canadian children, aged 0 to 14 years, have asthma and it is the leading cause of hospitalization for children, presenting a significant financial burden on the health care system (3). There is a recurring increase in ED visits, hospital admissions, and unscheduled physician consultations for school age children shortly after the return to school each September. Rhinovirus infections, allergens, and decreased use of asthma medications during the summer all contribute to this problem. ACES is used to monitor asthma-related ED visits by children as they return to school each fall, and, as expected, a significant rise is observed each year. Health professionals use this information to assess the annual epidemic. ACES can assist prevention efforts by identifying regions with high rates of asthma and therefore the greatest need for intervention strategies.

1.3. Future Directions

Ongoing upgrades and to ACES are in progress to include all hospitals across Ontario and to improve access to ACES information products for our healthcare partners. ACES continues to improve its user interface and built-in analytics with technological advances. The scope of ACES is able to expand according to need. For example, ACES provides key provincial surveillance of opioid overdose, mental health surveillance, and emerging health threats including infectious disease outbreak or the identification of emerging substance abuse issues. It is used to monitor mental health status during and after major events (e.g., extended extreme heat events, terrorist events in other parts of the world) and during mass gatherings. ACES' flexibility enables the rapid development of new surveillance tools to serve evolving healthcare needs for Ontario.

SECTION 2: THE SCIENCE OF ACES

2.1. A Short History of Syndromic Surveillance

The origins of syndromic surveillance are in epidemiologic surveillance—the traditional systematic collection, evaluation, and dissemination of health information. Traditional surveillance methods can be passive (e.g., regular disease reporting to public health authorities) or active (e.g., using patient surveys to gather information). Syndromic surveillance is a distinct form of passive surveillance where automated data acquisition is used to monitor behaviours reflecting symptoms (or syndromes). Examples include the monitoring of electronic/online absenteeism records from schools or work settings, over-the-counter drug sales, internet search data, social media postings, or ED triage records. Data is available in real time and with no additional input needed from those who gather the data.

Syndromic surveillance drew attention and increased research interest during the perceived threat of terrorism, particularly bioterrorism, following 9-11 in 2001. The occurrence of pandemic threats (e.g., SARS from November 2002 to July 2003) secured the utility and value of real-time syndromic surveillance beyond bioterrorism, as public health agencies recognized inadequacies in emergency preparedness and the need for enhanced surveillance techniques.[8] Methods that could provide early detection of intentional poisoning of water or food, for example, were needed in real time to ensure rapid treatment and allocation of resources.

Advances in electronic data collection led the way for modern syndromic surveillance systems to provide efficient, sensitive, and real-time capabilities to detect and statistically analyze aberrations from historical trends. Geospatial analytics allow for visualization of these trends at regional, national, and global levels. If aberrations are detected in a timely manner, reasonable public health measures can potentially minimize adverse health outcomes and the addition of geographical information allows for population-specific interventions. Interventions might include but are not limited to, the reallocation of health care resources to high-risk populations, public health reassurance, and health care recommendations. For example, if a syndromic surveillance system indicates that there is heightened influenza risk within a specified region, dedicated clinics can be opened to treat patients, possibly reducing patient influx into local acute care facilities where resources are often already overextended and reducing transference of disease.

An efficient syndromic surveillance system uses data that is routinely collected for other reasons (e.g., acute care triage registration data), recorded and accessible electronically, and available in near-real time or real time. The information derived from the data collection need to be validated against traditional data sources (e.g., laboratory results, clinical diagnostic records). Acute care triage records submitted at patient registration provide can provide truly real-time surveillance—EDs are open twenty-four hours per day, every day of the year and serve a wide-range of patients for a wide range of reasons.

2.1.1. *The Development of ACES*

In September of 1999, researchers at the University of Pittsburgh initiated the prototype Real-time Outbreak and Disease Surveillance (RODS)[9] system to monitor and characterize illness outbreaks using data from electronic ED triage records. The success of this system, combined with the timeliness of its initiation immediately before 9-11, helped it evolve into a much larger surveillance network. It was used to monitor illness and possible outbreaks during the 2002 Olympic Games in Salt Lake City and has been deployed by several cities and US states to monitor both disease outbreak and pandemic. RODS categorizes ED visits into syndromes using probabilistic algorithms that analyze each record according to the words or phrases included in its chief complaint (see footnote 5, page 3). The earliest RODS syndromes reflect its origins in monitoring for bioterrorism:

1. **Gastrointestinal**: nausea or vomiting, diarrhea, abdominal pain/cramps/swelling.
2. **Constitutional**: non-localized systemic complaints, including fever, faintness, lethargy.
3. **Respiratory**: congestion, cough, sore throat, asthma, pneumonia.
4. **Rash**: any description of a rash.
5. **Hemorrhagic**: bleeding from any site.
6. **Botulinic**: ocular abnormalities, difficulty speaking and swallowing.
7. **Neurological**: non-psychiatric complaints.
8. **Other**: pain or process in system/area not monitored.

In 2003, RODS was made freely available as open source software, and a group of researchers from KFLAPH, Queen's University, and two local hospitals used this platform as the framework for the Emergency Department Syndromic Surveillance (EDSS) system—later to be rebranded as ACES. EDSS was initiated in September 2004 as a two-year collaborative pilot project with financial support from the MOH and the Public Health Agency of Canada. Major modifications were made to the RODS software, including the addition of geospatial mapping, alert optimization, new syndrome classifications, and the inclusion of Canadian Triage Acuity

[8] See various reports on the need for enhanced public health in Ontario such as the Naylor Report (1) and the Campbell Report (2).

[9] Information on the RODS prototype can be found at the RODS Laboratory website: *rods.pitt.edu/site/content/view/15/36/*

Score[10] (CTAS) scores and febrile respiratory illness (FRI) screening results. The initial syndromes differed slightly from RODS': (1) *Gastroenteritis*, (2) *Fever/ILI*, (3) *Respiratory*, (4) *Dermatologic Infectious*, (5) *Severe Infectious*, (6) *Asthma*, (7) *Neurological Infectious*, and (8) *Other*, which included all visits that were not otherwise classified. *Other* accounted for most ED visits. Results were aggregated and displayed using tables, graphs, and maps, and alerts were generated as statistical aberrations from counts higher than expected historical thresholds.

During the initial two-year pilot project, an outbreak of *Salmonella enteritidis* in November and December of 2005 provided a pragmatic illustration of the effectiveness and value of the EDSS system. At the time, the EDSS was operational with only the hospitals within the KFLAPH catchment area. EDSS allowed for real-time monitoring and identification of patients faster than would have occurred previously, as well as a faster linkage of front-line health workers to the suspected cases for identification of the outbreak vector. The EDSS system clearly facilitated faster response from—and better communication between—both public health and acute care workers. These observations and results are noted in the Canadian Journal of Emergency Medicine (4). Furthermore, results verifying and validating the EDSS system for monitoring respiratory illnesses with the NACRS dataset and Telehealth Ontario were published (5)— strong Spearman's correlations were observed between visits categorized as respiratory illness and data from Telehealth (r = 0.91) and NACRS (r = 0.98).

Expanding upon these results, the efficiency of the EDSS system over primary care sentinel surveillance was established and described an article published by the ACES team in 2013, *Emergency department surveillance as a proxy for the prediction of circulating respiratory viral disease in Eastern Ontario* (6). ED visits were categorized by the EDSS as either ILI or respiratory as a proxy for the detection and prediction of actual lab-confirmed cases of respiratory viral diseases and influenza. The syndromes were defined from key words found in chief complaints: for respiratory illness, "cough", "sore throat", "upper respiratory tract infection", and "sinus infection" were used; for influenza-like-illnesses, "fever" and influenza-related symptoms were used. The results were aggregated weekly from the EDSS and compared to lab results. Significant correlations were measured for selected respiratory viruses and ED visits, and a general lag time of about two weeks was found between the acute care data and test results.

In 2014, the EDSS system was overhauled to reflect both the expansion of the participating hospitals across Ontario, and the development of additional and more specific syndrome classification. At the same time, numerous technological improvements were made. To reflect these changes, the system was renamed Acute Care Enhanced Surveillance or ACES. The number of hospitals participating is currently over 95% of all Ontario hospitals. The list of syndromes has been expanded to 80 health conditions (Appendix B: ACES Syndromes). The technological changes to ACES included several new and/or enhanced epidemiological assessment tools, including the following:

- improvements in algorithms for more accurate syndrome classification,
- intuitive graphing capabilities,
- built-in calculations of standard deviations and moving averages,
- monitoring capabilities are updated to reflect real-time values instead of arbitrarily fixed intervals, and
- visit and/or admission volumes can be based on either hospital location or patient address.

2.2. Natural Language Processing for Syndrome Classification

To understand the methods used to classify the text in chief complaints into specific syndromes, some concepts of machine learning need to be explored. Machine learning deals specifically with the construction of classification algorithms that can learn from data. ACES uses natural language processing (NLP) algorithms, which are those algorithms designed to enable a computer system to understand human text. NLP algorithms are used in daily life such as email spam detectors.

NLP began in the 1950s at the intersection of artificial intelligence and linguistics. Initially, it was considered a quest towards automatic translation, with much emphasis on translating Russian into English reflecting its roots in the Cold War. The task proved much more difficult than expected; simple hand-written rules of direct, word-for-word translation are not sufficient due to the complex, unrestricted, and ambiguous nature of language. NLP must extract meaning from text, and deal with spoken or written prose that is not grammatically correct. Out of these restrictions, statistical NLP methods developed, with probabilistic approaches that replace numerous detailed rules with statistical frequency information. The algorithms are refined, or able to learn, through training the program with large amounts of data with the correct answers, and then testing the robustness of the system with an unknown data set, and then repeating until the system performs satisfactorily. The algorithms do not rely on key word searches, but rather probabilistic decisions based on attaching learned weighted values to each word, part of word, or phrase in the chief complaints. The algorithms do not supersede hand-written rules but are complementary.

Medical records are a challenge for NLP algorithms. Chief complaints, for example, are written to be concise descriptions

[10] CTAS: Canadian Triage Acuity Score. See *http://ctas-phctas.ca/*

of the reason for a visit to the ED; therefore, chief complaints are often written with abbreviations, context-sensitive vocabulary, idiosyncratic or hospital-specific nomenclature, and often misspellings occur under the inherent demanding conditions in acute care settings. Furthermore, a single symptom may be observed for several possible diagnoses. For example, fever is associated with numerous conditions. Despite these limitations in diagnostic precision, chief complaints are of critical value to syndromic surveillance; they are available in real-time, whereas vetted diagnostic codes (i.e., MRDx codes using ICD-10 codes) are often not available for several days to weeks for an individual record.

The original EDSS system, based on RODS, used only one type of NLP algorithm, Naive Bayes (NB), to categorize the ED visits into its eight syndromes. This text classifier was called the Complaint Coder (CoCo); it was found to be problematic in two key ways: (1) the algorithm classifies using just single words, not phrases, and (2) the NB system assumes statistical independence between words in the chief complaint. To enable greater flexibility and potentially greater statistical accuracy, for a short period, EDSS (and later ACES) displayed the results of several text classifiers that used various different statistical methods to improve classification and users were able to choose which classifier to use with each data query. These 6 classifiers were run in the EDSS/ACES system for nearly 3 years with the resulting classifications for each algorithm being available for users to compare. The classifiers included were Balanced Winnow, C4.5 Decision Tree, Maximum Entropy (ME), Monte Carlo ME, NB, and Winnow2[11]. In early 2017, the ACES team removed all but ME classifier, making it the system default option. The other classifiers were removed for the following reasons:

- to increase ACES' processing power and speed,
- validation results indicated ME the best option for classifying hospital record data, and
- ACES users were not using the other classifiers.

The ME classifier analyzes the occurrence of character sequences rather than whole words. ME text classifiers do not assume terms are independent of each other. The ME classifier is particularly useful when nothing is known regarding the prior distributions of categories, and the terms cannot be assumed to be independent, as is the case for the categorization of the words and partial words in chief. The ME algorithm computes many different probabilities for the association of the terms and chooses the class selection that has the highest associated entropy, or the largest probability distribution. ME has a wide range of applications, such as sentiment analysis, language detection, and topic classification.

Syndrome Validation

As described in previous sections, the ACES system uses a ME classifier to sort hospital records into syndromes. The classifying algorithm uses text in triage records' chief complaints, which tend to be brief and can include medical jargon, idiosyncratic short forms, and spelling mistakes. Furthermore, chief complaints are the triage nurse's interpretation of a patient's reason for visiting the ED, and do not necessarily reflect the final diagnosis. It is, therefore, very difficult to diagnose underlying conditions from the presentation of non-specific symptoms. To ensure that ACES syndromes are meaningful aggregates of chief complaints, the accuracy of the diagnoses that the classifier is predicting (i.e., the syndrome) are assessed in comparison to retrospective acute care "gold standard" data available from CIHI: NACRS is used for ED visits and DAD for hospital admission. NACRS and DAD are the national repositories for acute care data in Canada; data is rigorously maintained and checked for accuracy. NACRS and DAD are generally available at least 3 months after the patient visit or admission, nullifying their use for emergency public health surveillance. Validation of ACES syndromes is completed at least yearly.

Validation of syndrome classification is made by correlating the daily number of ED visits categorized into a specific syndrome with its corresponding time series of diagnostically defined data compiled by NACRS (for ED visits) or DAD (for hospital admissions). Standardized diagnostic codes are made by Canadian hospitals using the *International Statistical Classification of Diseases and Related Health Problems 10th Revision* (ICD-10) coding system. ICD-10 codes are recorded by specialists into patient records using the comprehensive notes made by healthcare professionals (i.e., attending physician, nurse). The coding specialist inputs ICD-10 codes into the patient's records after they have been examined (and treated, when applicable). Coding specialists are trained to ensure coding consistency between hospitals and there are specific codes for disease, injury, causes of death, as well as external causes of injury and poisoning. By comparing counts of specific ACES syndromes to counts of corresponding ICD-10 diagnostic codes, the validity of the syndrome is quantified enabling both estimates of its accuracy and measures by which the syndrome classification can be honed and improved.

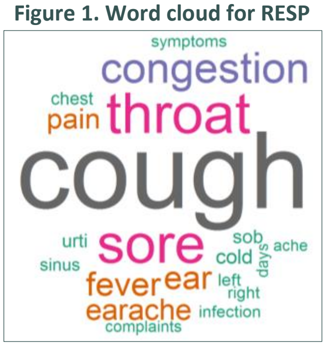
In the following discussion, the validation process is described for comparing ACES syndromes for ED visits to NACRS data; the

[11] These algorithms are based on the MALLET Machine Learning Toolkit, open-source software developed at the University of Massachusetts, Amherst.

same process is used to compare hospital admissions to DAD data. Pearson correlation coefficients (r)[12] are used to describe the relative similarity between the datasets for weekly, bi-weekly or twenty-eight day moving averages. In some cases, where there are relatively few observed cases, monthly cumulative sums must be used to ensure sufficient sample sizes for comparison. Pearson correlation values between 0 and 0.25 indicate poor correlation, values from 0.25 to 0.5 indicate moderate correlation, values from 0.5 to 0.75 indicate good correlation and values >0.75 indicate excellent correlation between datasets. These numbers roughly correspond to the percent of variation in one dataset that can be explained by variation in the second dataset.

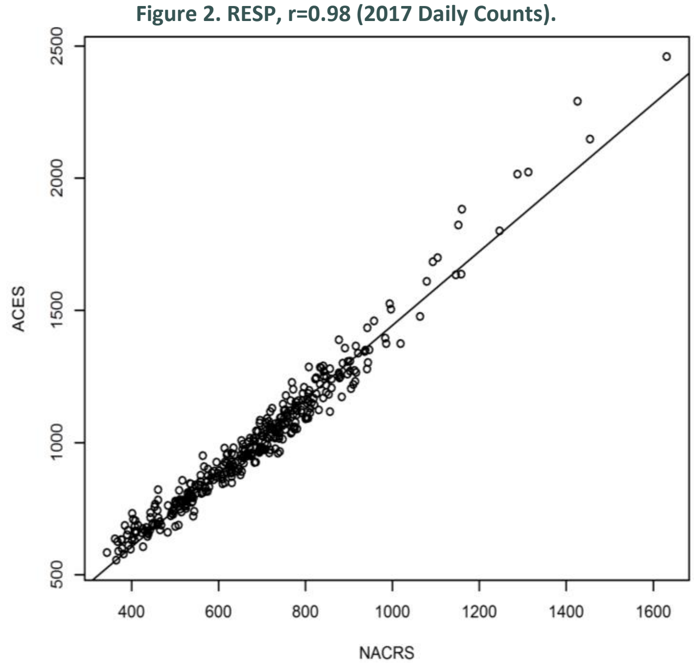
Examples of Syndrome Validation. Word clouds are included in validation reports to illustrate the most common free text words in each syndrome. For example, the word cloud in Figure 1 shows the words most common to the RESP (respiratory) syndrome; the size of the word indicates is relative frequency. Words such as "cough", "throat" and "sore" occur more often than "travel" and "days" in RESP. The ICD-10 diagnostic codes that represent the disease symptoms represented by RESP were determined by a team of emergency physicians, epidemiologists, and a coding specialist. The ICD-10 codes collated for RESP validation are in Table 1. Figure 2 shows the linear correlation between ACES and NACRS for RESP: daily counts are shown for 2017 and all hospitals reporting to ACES. The correlation between datasets is excellent (r=0.98), indicating that RESP can be used with statistical certainty to represent true trends in ED visits for the diagnoses in Table 1. Word clouds and validation statistics are shown for AST (asthma), ENVIRO (exposure to heat and cold), GASTRO (gastrointestinal), and MH (mental health) are shown in Figures 3 to 6, respectively. See Section 4 for ICD-10 codes used to validate each syndrome. Validation statistics are measured annually (or as needed) for all syndromes.

Figure 1. Word cloud for RESP



Source: Syndrome Validation Report, KM 2018

Figure 2. RESP, r=0.98 (2017 Daily Counts).



Source: Syndrome Validation Report, KM 2018

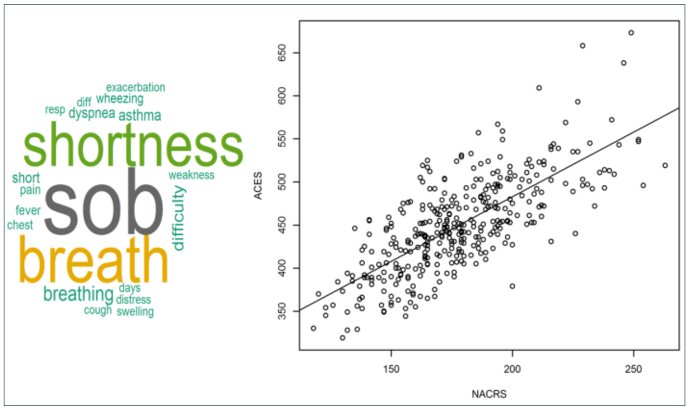
Table 1. ICD-10 codes used for validation of RESP

ICD-10 Code	Medical Diagnosis
J00	acute nasopharyngitis
J01	acute sinusitis
J02	acute pharyngitis
J03	acute tonsillitis
J04	acute laryngitis and tracheitis
R05	cough

Source: Syndrome Validation Report, KM 2018

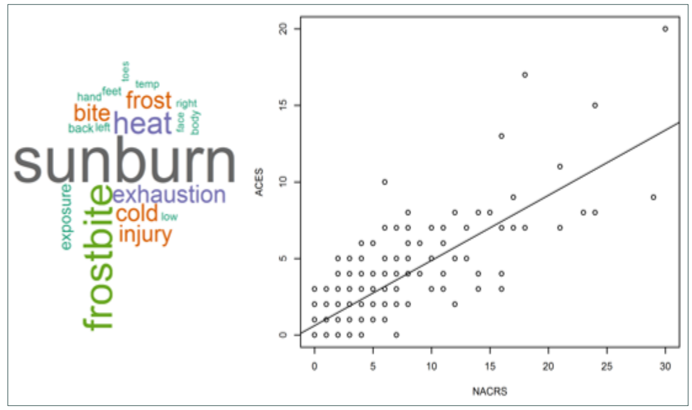
[12] Pearson's correlation coefficients are measures of linear association between two variables. See *link.springer.com/referenceworkentry/10.1007%2F978-1-4020-5614-7_2569*

Figure 3. AST, r=0.74 (2017 Daily Counts).



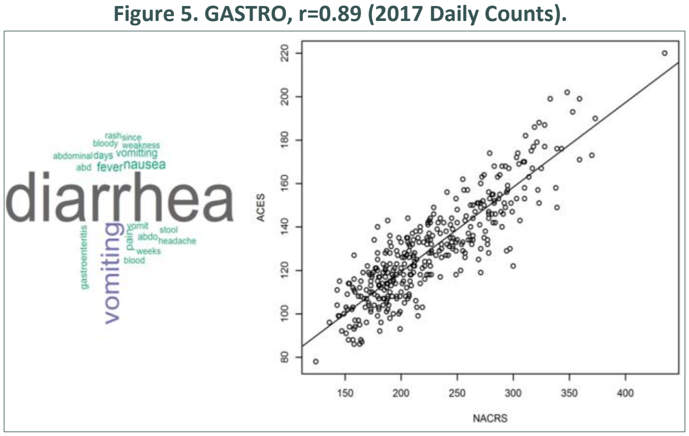
Source: Syndrome Validation Report, KM 2018

Figure 4. ENVIRO, r=0.81 (2017 Daily Counts).



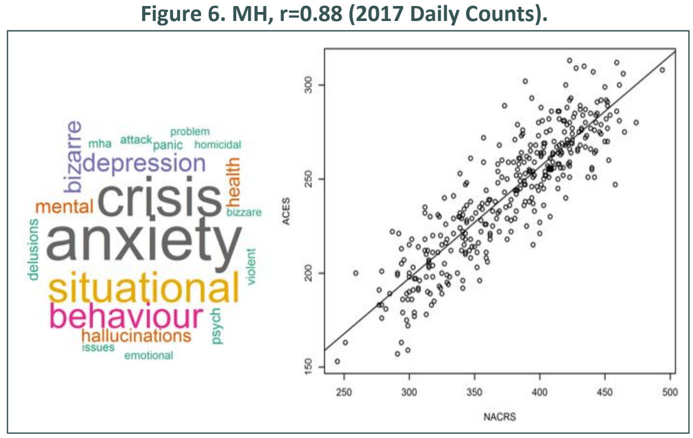
Source: Syndrome Validation Report, KM 2018

Figure 5. GASTRO, r=0.89 (2017 Daily Counts).



Source: Syndrome Validation Report, KM 2018

Figure 6. MH, r=0.88 (2017 Daily Counts).



Source: Syndrome Validation Report, KM 2018

2.3. Alerts and Outbreaks

According to the US Centers for Disease Control and Prevention (CDC), the aim of syndromic surveillance is to identify unusual disease clusters through the detection of early symptomatic cases to enable outbreak detection that is earlier in time than would otherwise occur with conventional reporting methods (7). Standard disease surveillance techniques include modelling disease incidence, prevalence, and geographical distribution. With the ability to automate disease and even syndrome-specific data, collecting data in real time and at regular intervals can facilitate early and rapid detection of an outbreak to enable timely public health interventions. ACES fulfills both of these constraints:

1. ACES employs automated and validated classification of real time data into syndromes, and
2. ACES enables real-time aberration[13] detection using time-series focused algorithms, whereby data is synthesized in real-time to detect aberrations as they occur.

ACES employs two families of alerting algorithms to detect aberrations from normal trends in ED visits and hospital admissions across Ontario and in real time. Aberrations may indicate a disease outbreak, the onset of a seasonal trend (e.g., influenza or asthma), or a problem with data transfer. The two families of alert algorithms are as follows, and are described in following sections:

1. cumulative sum (CUSUM) alerts including CUSUM1, CUSUM2, and CUSUM3, representing varying sensitivity to timelines, and
2. Statistical Process Control (SPC) alerts, including extreme, on edge, and trend.

2.3.1. *The Cumulative Sum Family of Alerts*

The Cumulative Sums (CUSUM) family of alerts is based on

[13] An aberration is defined as when a data point, or sequential data points, in a time series exceeds a certain value or behaves in a way that is not likely to have occurred by chance alone.

algorithms developed by the CDC's Early Aberration Reporting System (EARS) to detect bioterrorism threats. EARS has been subsequently employed by a wide range of health departments across the United States and Canada and was designed to provide enhanced surveillance for a short duration around a discrete event (such as a sporting event like the Olympics or a political convention) for which very little background data existed, and therefore alert algorithms use just seven 24-hour periods of data to calculate expected daily counts. The set of three EARS algorithms used by ACES are adapted to incorporate a cumulative approach to evaluating the data and are based on whether daily syndrome ED counts exceed the expected value by a certain threshold with varying sensitivity. Aberrations in daily counts of ED visits that are above what is expected are assessed according to one-sided CUSUM calculations. Daily ED counts are described as z_t value that standardize the daily count to the mean and standard deviation for the previous seven days, as follows:

$$z_t = \frac{[x_t - (\mu + \sigma)]}{\sigma}$$

where x_t is the current daily ED count at time t, and μ is the mean and σ is the standard deviation. Consecutive daily ED counts are then compared using the CUSUM formula,

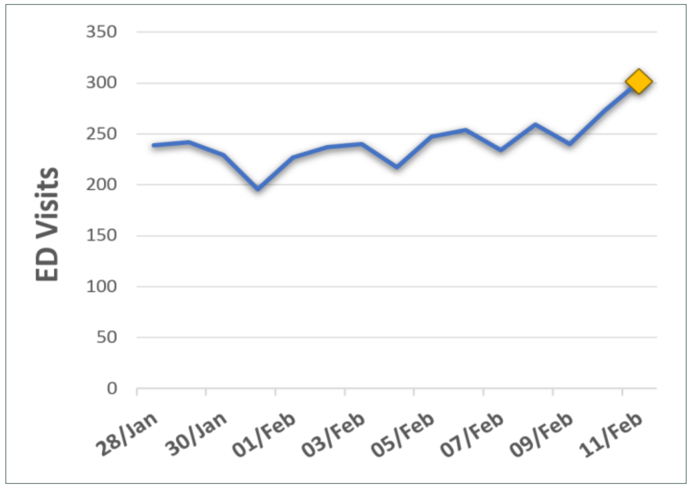
$$S_t = \max\{0, S_{t\text{-}1} + z_t\}$$

where the current CUSUM, S_t is the maximum value of zero or the sum of the previous day's CUSUM, $S_{t\text{-}1}$, and z_t; if $S_t \geq 3$ an alert is triggered. This threshold is generally accepted as optimal, but a lower value would increase sensitivity. Sensitivity can also be changed by adjusting the time used to calculate the mean and standard deviation to which daily counts are standardized. CUSUM alerts in ACES describe three levels of sensitivity: CUSUM1 (mild sensitivity), CUSUM2 (medium) and CUSUM3 (ultra).

The following example will illustrate the differences between the CUSUM alerts. The daily counts for ED visits classified as ASTHMA are shown in Figure 7: it is unclear if ED counts observed on 11-Feb (yellow marker) are high in comparison to what may be expected by chance. Using the CUSUM alert method described above, a threshold of CUSUM ≥ 3 is used. Mean (µ), standard deviation (σ), and CUSUM score (z_t) are calculated beginning Feb-04, the first date with seven previous daily ED counts (Table 2). Using equations 1 and 2, z_t and CUSUM$_t$ are calculated for subsequent days. Note that CUSUM$_t$ values approach zero when hospital visit counts, generally, approach the mean. This method is effectively a measure of a value's proximity to the mean. Using this method, the daily ED count for Feb-11 would trigger an alert. ACES would notify the administrator of that hospital that the counts for asthma need to be examined in further detail.

One of the main benefits of CUSUM methods for aberration detection is the short period of background data required to calculate alerts. Again, sensitivity to changes in the daily ED counts can be varied according to need and the normal aberrations observed for that data. In the above CUSUM (specifically, CUSUM1) calculations, the mean daily ED visits are determined from the seven days previous to 11-Feb and changes in sensitivity can be achieved by changing the baseline of seven days from $t_{\text{-}3}$ to $t_{\text{-}9}$ (Figure 8), as will be discussed for CUSUM2 and CUSUM3. The benefits of each CUSUM approach are discussed below.

Figure 7. ED Visits for Asthma



Source: KM 2015

Table 2. CUSUM1 Alert, Example of Calculation of Variables

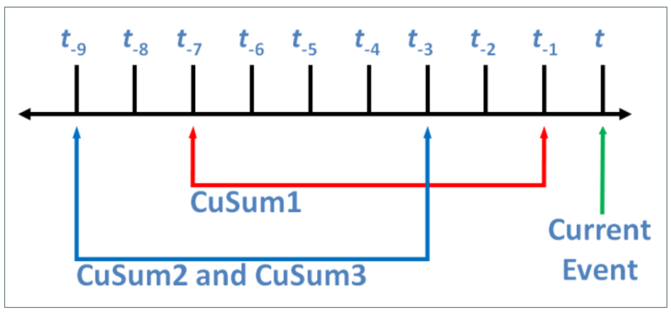
DATE	daily counts	µ	σ	z	CuSum1 ($t_{\text{-}1}$ to t)	Alert?
28-Jan	239	232.3				
29-Jan	242	233.3				
30-Jan	229	229.6				
31-Jan	196	227.6				
01-Feb	227	223.6				
02-Feb	237	222.9				
03-Feb	240	225.4				
04-Feb	217	230.0	16.0	-1.81	0	×
05-Feb	247	226.8	16.1	0.25	0.25	×
06-Feb	254	227.6	17.0	0.56	0.80	×
07-Feb	234	231.1	19.7	-0.86	0	×
08-Feb	259	236.6	12.3	0.82	0.82	×
09-Feb	240	241.1	14.0	-1.08	0	×
10-Feb	273	241.6	13.9	1.27	1.27	×
11-Feb	301	246.3	18.2	2.01	3.28	✓

Source: KM 2015

The previous example describes the calculations involved in a CUSUM1 alert, considered an alert of mild sensitivity. The means (μ) and standard deviations (σ) used to calculate CUSUM1 are based on daily ED visit counts for the seven days before the current day, that is, from t_{-1} to t_{-7} (Figure 8). The threshold limit is defined as three in ACES, and therefore, an alert is flagged when CUSUM ≥ 3. The sensitivity of CUSUM1 can be increased or decreased by changing this threshold. It is important to note that, because the current daily count is compared to the mean and standard deviation of the previous seven days, if an aberrant value is detected on the current day (t), the CUSUM1 calculated for the next day (t_{+1}) will be less likely to surpass the threshold as the previous day's higher-than-average value will increase the values of both the mean and standard deviation.

CUSUM2 is calculated using the same methods as CUSUM1, but with a shifted baseline for calculating the mean (μ) and the standard deviations (σ) (Figure 8). Changing the timeline for these calculations may increase the sensitivity of this method; the additional two-day lag period between the current count and the values used to calculate the mean may increase sensitivity on subsequent days. The same threshold is used as with CUSUM1, that is, CUSUM2 ≥ 3. The increase in sensitivity is best described visually: the data in Figure 7 and Table 2 are presented again with two additional days included (Figure 9). You can conceptualize the difference this makes by considering the values used to calculate μ on 12-Feb; for CUSUM2, the ED counts from the two days before the current value are not included in the calculation (Table 3). The μ is not, therefore, skewed to a higher number by the anomalously high ED visits observed on 11-Feb. Thus, CUSUM1 does not and CUSUM2 does generate an alert on 12-Feb; likewise, CUSUM2 also generates an alert on 13-Feb.

Figure 8. Timeline for CUSUM Alerts



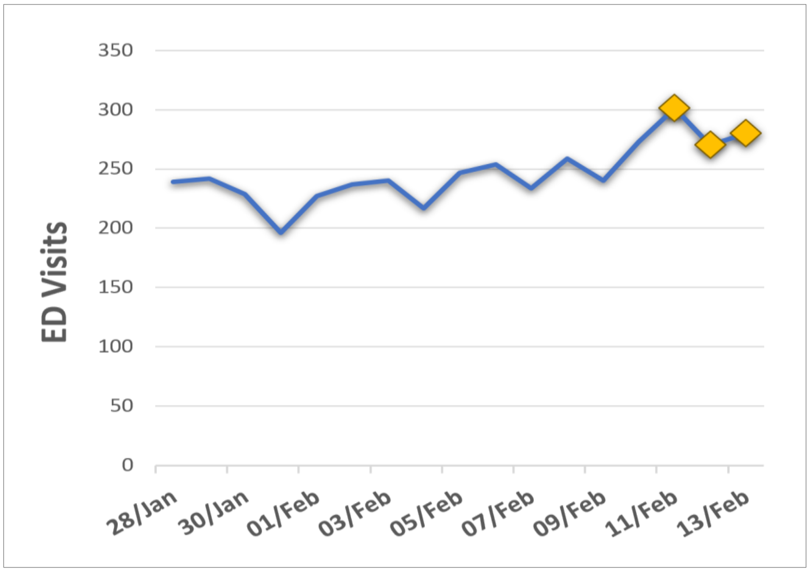
Source: KM 2015

Table 3. Comparison of CUSUM Alerts, Example of Calculation of Variables

DATE	daily counts	CUSUM1					CUSUM2					CUSUM3	
		μ	σ	z	(t_{-1} to t_{-7})	Alert?	μ	σ	z	(t_{-3} to t_{-9})	Alert?	See text	Alert?
28-Jan	239	232.3											
29-Jan	242	233.3											
30-Jan	229	229.6											
31-Jan	196	227.6											
01-Feb	227	223.6											
02-Feb	237	222.9											
03-Feb	240	225.4											
04-Feb	217	230.0	16.0	-1.81	0	×							
05-Feb	247	226.8	16.1	0.25	0.25	×							
06-Feb	254	227.6	17.0	0.56	0.80	×	230.0	16.0	0.50	0.50	×	0.50	×
07-Feb	234	231.1	19.7	-0.86	0	×	226.9	16.1	-0.56	0.00	×	0.50	×
08-Feb	259	236.6	12.3	0.82	0.82	×	227.6	17.0	0.85	0.85	×	1.35	×
09-Feb	240	241.1	14.0	-1.08	0	×	231.1	19.7	-0.55	0.30	×	1.15	×
10-Feb	273	241.6	13.9	1.27	1.27	×	236.6	12.3	1.96	2.26	×	3.41	✓
11-Feb	301	246.3	18.2	2.01	3.28	✓	241.1	14.0	3.28	5.55	✓	8.11	✓
12-Feb	270	258.3	22.8	-0.48	2.79	×	241.6	13.9	1.05	6.60	✓	8.86	✓
13-Feb	280	261.6	22.5	-0.12	2.61	×	246.3	18.2	0.85	7.45	✓	7.45	✓

Source: KM 2015

Figure 9. ED Visits for Asthma, Additional Data



Source: KM, 2015

The most sensitive CUSUM alert is CUSUM3. The calculation of this statistic depends on CUSUM2 values: it is the sum of CUSUM2 from the current day and the previous two days, but only if the previous two days did not generate alerts. If the previous days' CUSUM2 did generate alerts, their values are set to zero, as in the following formula,

$$\text{CUSUM3} = \sum S_{t_0} + S_{t\text{-}1} + S_{t\text{-}2}$$

where S_{t_o} is the CUSUM2 value for the current day and $S_{t\text{-}1}$ and $S_{t\text{-}2}$ are the CUSUM2 values for the previous two days. If $S_{t\text{-}1} > 3$, then $S_{t\text{-}1} = 0$ and if $S_{t\text{-}2} > 3$ then $S_{t\text{-}2} = 0$ (ACES' alert settings will trigger a CUSUM2 alert if CUSUM2 > 3). Again, referring to the data shown in Figure 8 with additional data shown in Table 3 and Figure 9, the relationship between CUSUM alerts can be observed: for this data set, CUSUM1 gives one alert on 11-Feb, CUSUM2 triggers three alerts on consecutive days (11-Feb to 13-Feb), and CUSUM3 has the same results as CUSUM2 except that an additional alert is calculated for 10-Feb. The calculation of the CUSUM alerts shown in Table 3 reveals the start of an elevation in ED counts on 10-Feb, and CUSUM3 gives a statistical foundation for concern.

2.3.2. *Statistical Process Control Alerts*

The Statistical Process Control (SPC) family of alerts were developed and used by the manufacturing industry to improve product quality by reducing product variability. During a manufacturing process, quality control and/or the stability of the process are monitored by measuring a defined parameter; generally, these measurements are amenable to graphical display as a function of time. SPC alerts are used to identify aberrations in indicators of quality control or process stability that are unlikely to be caused by chance alone. Measurements of the parameter arecompared to their means and standard deviations over definedtime periods, and an alert is triggered according to differences in the current measurement from the mean and within defined levels of standard deviation, depending on the type of SPC alert. SPC alert methods have been used to monitor and improve hospital performance and are used in disease surveillance to detect large increases in disease reports for the *National Notifiable Diseases Surveillance System* of the *Centres for Disease Control*.

In ACES, three different SPC alert types are used: **extreme**, **trend**, and **OnEdge**. Means and standard deviations are typically calculated from the preceding two weeks of ED visit counts, for a particular syndrome. It may be useful to change the sensitivity of an SPC alert by changing the time periods used for calculating means and standard deviations. For every data point measured, three upper control limits (UCL, UCL2 and UCL3) and three lower control limits (LCL, LCL2 and LCL3) are calculated as follows, **where** μ and σ are the mean and the standard deviation for the previous fourteen days, respectively:

$$\text{UCL} = \mu + \sigma \qquad \text{UCL2} = \mu + 2\sigma \qquad \text{UCL3} = \mu + 3\sigma$$

$$\text{LCL} = \mu - \sigma \qquad \text{LCL2} = \mu - 2\sigma \qquad \text{LCL3} = \mu - 3\sigma$$

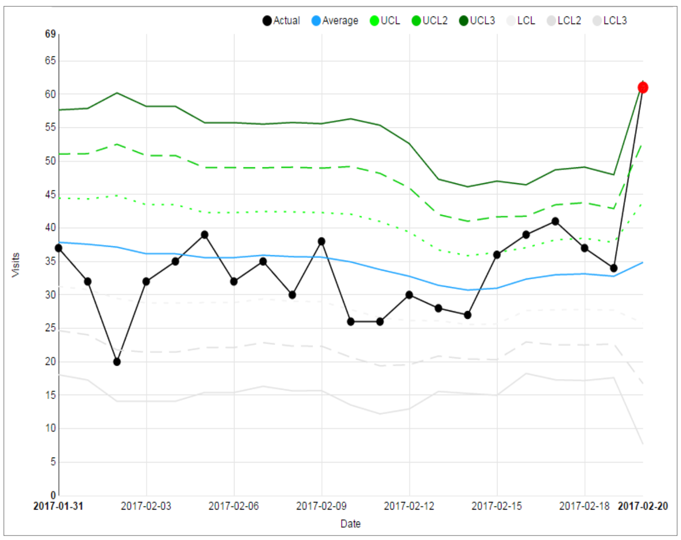
SPC alerts in ACES are associated with only the UCL calculations, as ED counts that are above the means are of epidemiological interest in determining possible public health threats.

Extreme. An extreme alert is the most intuitive of the SPC alerts; it is generated if the current day's ED visit count is greater than three standard deviations from the mean (i.e., current count > UCL3). Assuming a normal distribution for the data, the probability that the one data point will be more than three standard deviations than the mean is 0.13%; therefore, a current count beyond three standard deviation of the mean has only a 0.13% chance of being due to chance alone. This is epidemiologically relevant as this alert would likely manifest as a very sharp incline compared to historic data and require immediate investigation to contain the issue. It would also be useful for hospital administration staff as this type of spike may require more staffing or diversion of patients to other hospital sites depending on the scale of the spike. An example of a counts leading to an extreme alert are shown in Figure 10: there were 62 ED visits for RESP on the 20th of February, just higher than the UCL3 (61), according to the equations above.

Trend. Unlike other alerts, a trend alert is not dependent on mean or standard deviation. A trend alert is triggered if the current visit count is the sixth in a row where all six counts are increasing. A trend alert, therefore, follows these conditions: count t_1 < count t_2 < count t_3 < count t_4 < count t_5 < count t_6. An example of this alert is shown in Figure 11 (next page); the highlighted data point is the sixth in a row where all six points are increasing from the previous point. A trend alert may reveal an increasing trend in counts before counts exceed the UCL. Six consecutive increasing points is statistically improbable and likely not due to chance alone. Trend alerts may identify subtle changes in ED visit/admissions patterns that are not identified by other surveillance methods that are relative to means and standard deviation.

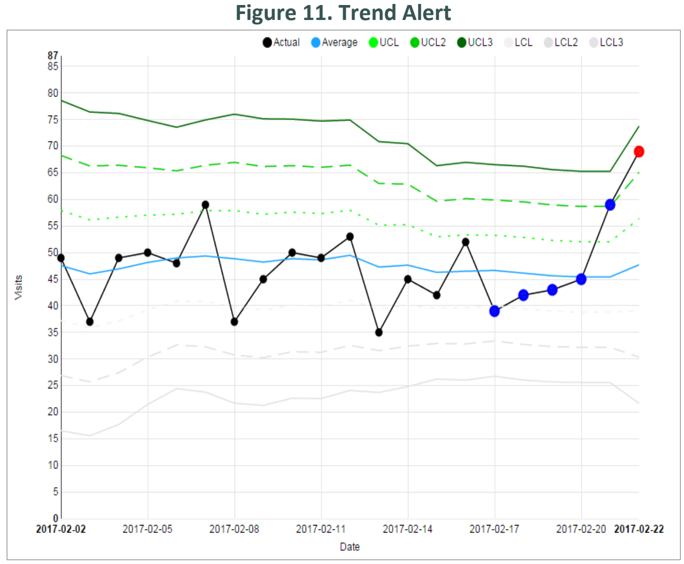
OnEdge. An on edge alert is generated if the current visit count is the second of any two of the last three counts greater than UCL2. The probability of this occurring by chance alone, assuming a normal distribution, is 0.16%. The red highlighted data point in Figure 12 (next page) is the second point (of three data points) that is greater than two standard deviations from the mean. Likewise, Figure 13 (next page) is a second example of where an on edge alert would be triggered, but the two points greater than UCL2 are not sequential.

Figure 10. Extreme Alert



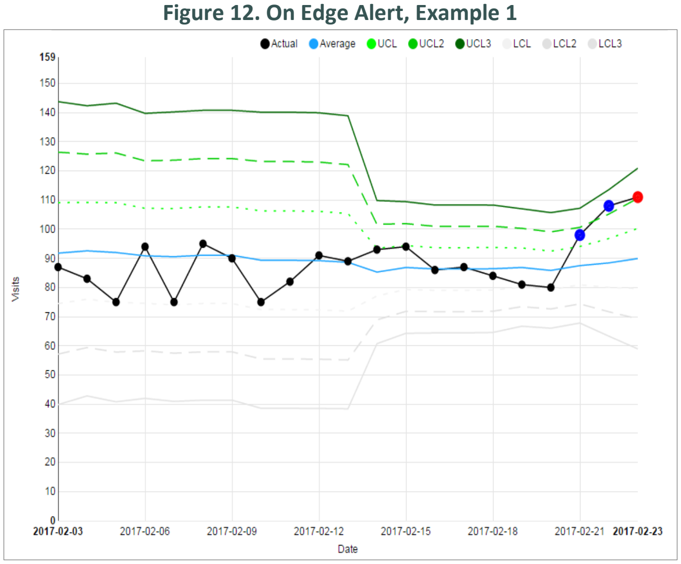
Source: ACES 2015

Figure 11. Trend Alert



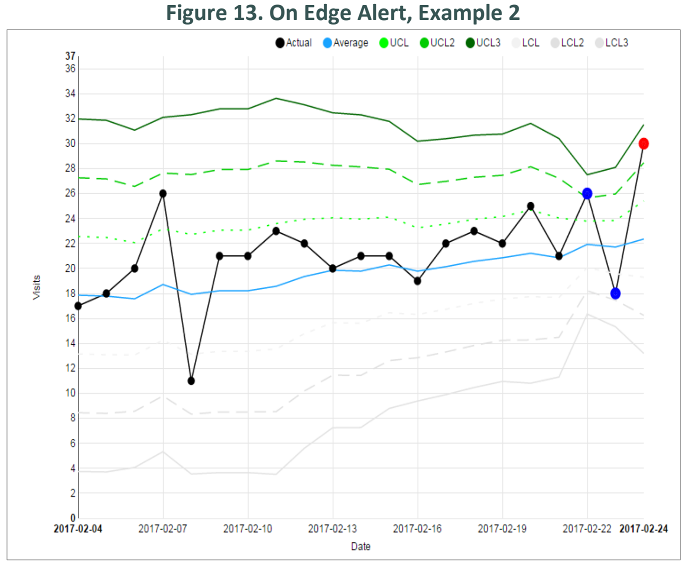
Source: ACES 2015

Figure 12. On Edge Alert, Example 1



Source: ACES 2015

Figure 13. On Edge Alert, Example 2



Source: ACES 2015

2.4. Quick Reference Guide for ACES Alerts and Further Resources

The following chart summarizes the alerts and their uses. For more information on alerting practices in ACES, see the following journal articles:

- *Real-Time Surveillance for Respiratory Disease Outbreaks, Ontario, Canada* (5)
- *Automated Mortality Surveillance in South-Eastern Ontario for Pandemic Influenza Preparedness* (8)
- *Risk Assessment During the Pan American and Parapan American Games, Toronto*, 2015 (9)
- *Characterizing the Effects of Extreme Cold Using Real-time Syndromic Surveillance, Ontario, Canada, 2010-2016* (10)

For general information regarding general syndromic surveillance alerting practices, see the following research reports:

- *The Bioterrorism Preparedness and Response Early Aberration Reporting System* (EARS) (11)
- *Comparing Syndromic Surveillance Detection Methods: EARS' Versus a CUSUM-Based Methodology* (12)
- *Statistical Methods for the Prospective Detection of Infectious Disease Outbreaks: A Review* (13)
- *Practical Comparison of Aberration Detection Algorithms for Biosurveillance Systems* (14)

Alert Name	Baseline	Rule (x = daily count)	Description	Strengths	Weaknesses
Cumulative Sum (CUSUM):					
CUSUM1 (C1) Mild Sensitivity	7 days t_{-1} to t_{-7}	C1 > 3; *when* $C1_t = \max(0, C1_{-1} + z_t)$ *and* $z_t = \frac{[x_t - (\mu+\sigma)]}{\sigma}$	Daily counts are standardized relative to mean values as z scores; C1 is sum of z for current and previous day's counts.	Requires 7 day baseline to calculate.	Second day of high counts is obscured (x_{-1} included in calculation of μ and σ).
CUSUM2 (C2) Medium Sensitivity	7 days t_{-3} to t_{-9}	C2 > 3; *when* $C2_t = \max(0, C2_{-1} + z_t)$ *and* $z_t = \frac{[x_t - (\mu+\sigma)]}{\sigma}$	Daily counts are standardized relative to mean values as z scores; C2 is sum of z for current and previous day's counts. NOTE: C2 has different baseline than C1.	Remains sensitive if x_{-1} or x_{-2} triggers alert.	
CUSUM3 (C3) Ultra Sensitivity	7 days t_{-3} to t_{-9}	C3 > 3; *when* $C3 = C2_t + C2_{-1} + C2_{-3}$ *and* $C2_x$=0 if > 3	Sum of C2 for current and 2 previous days. $C2_x$ is 0 if it triggered an alert (i.e., greater than 3.		
Statistical Process Control (SPC):					
Extreme	14 days t_{-1} to t_{-14}	x_t > UCL3	Daily count is greater than 3σ above the μ.		
Trend		$x_{-5} < x_{-4} < x_{-3} < x_{-2} < x_{-1} < x_t$	6th day of six days of increasing counts.	Identify trend before x_t exceeds UCL3.	
On Edge	14 days t_{-1} to t_{-14}	x_t > UCL2 for 2 of 3 consecutive counts	Any 2 of the last 3 days are greater than 2σ above the μ.		

SECTION 3: USER INTERFACE GUIDE

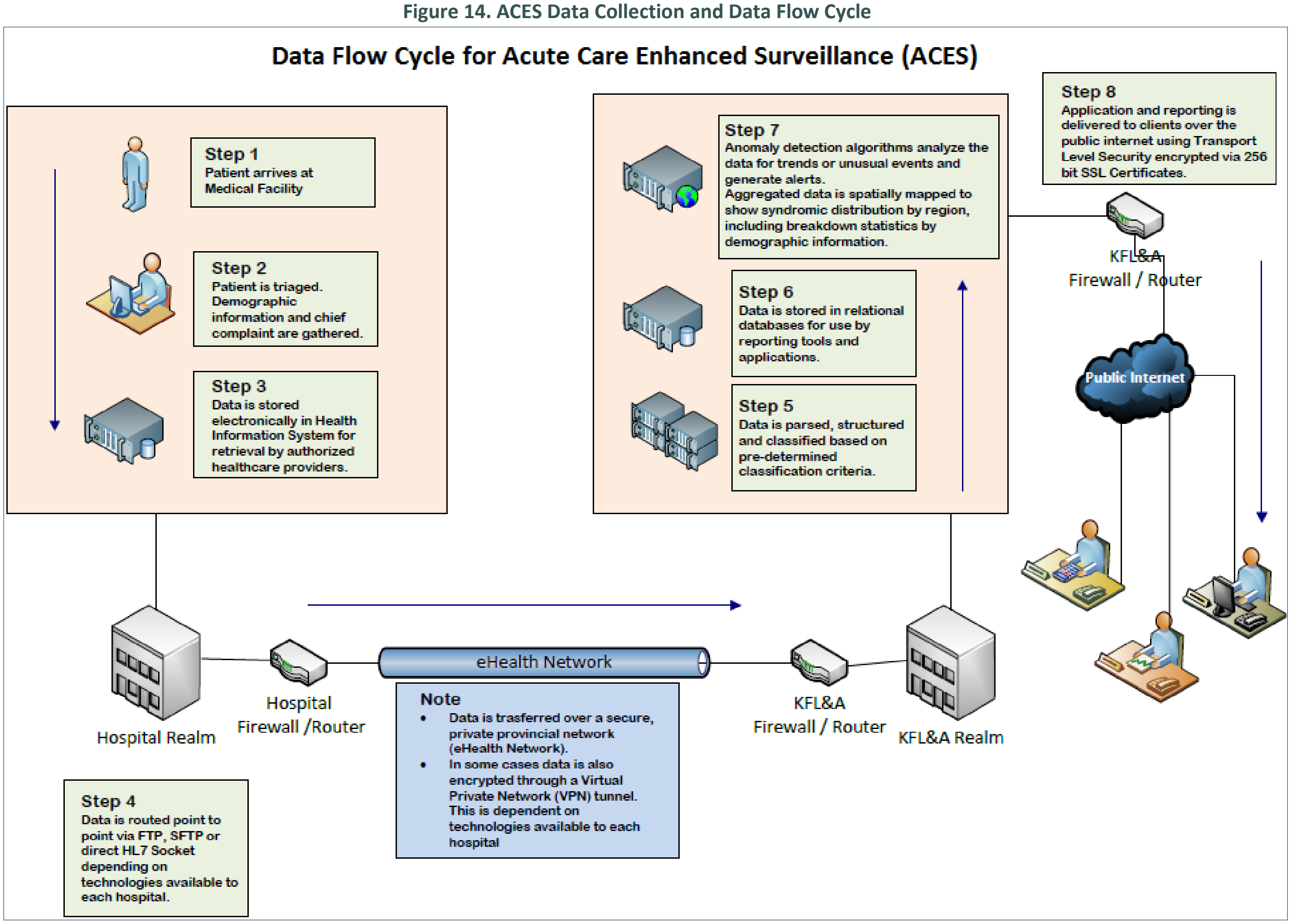
3.1. System Overview

The following section provides guidance for both new and advanced users. Instructions are given in all functions ranging from logging in to making full use of ACES' alerting capabilities.

3.1.1. *Data Collection*

All data for ACES is collected by participating health care facilities during the registration and triage process. When a patient presents at the ED, details describing both the patient and the visit are entered into the hospital's computer system at registration. Without any additional action needed on the part of hospital staff, ACES captures information from triage records with no measurable impact on staff workload. Information from the triage records that are collected by ACES include patient demographics (age, sex, residential postal code), the date and time of the visit, chief complaint as recorded by the triage nurse, CTAS[14], arrival by ambulance, admission diagnosis (if recorded and available), discharge diagnosis (if available), and admission to intensive care, if applicable. To ensure identity protection and privacy requirements, no direct personal identifiers (i.e., name or health insurance number) are collected by ACES, and the data is sent from hospitals to KFLAPH's data centre over the secure Ontario e-Health network (Figure 14).

Figure 14. ACES Data Collection and Data Flow Cycle



Source: KM 2015

[14] CTAS: Canadian Triage Acuity Score. See *http://ctas-phctas.ca/*

3.1.2. *Data Processing*

Data collected from each participating acute care facility are stored at KFLAPH's secure data centre. Each patient visit is classified into one of ACES pre-defined syndromes[15] using the NLP processes described in Section 2. Briefly, words, phrases, or parts of words found in the chief complaint (or reason for admission) are used to classify each visit into a most likely syndrome. Counts for individual syndromes are monitored using anomaly detection methods to identify an outbreak or concerning trends. If an abnormal number of visits for a syndrome are detected, alerts generated by the ACES system are immediately posted to the ACES interface. Epidemiologists and other health professionals can use system to monitor and assess the ED visits leading to the alert. They can investigate patterns related to demographics, location, or timing of the cases that would justify further investigation by public health staff. The data is collected in real-time and is based on disease symptoms, rather than diagnosis; therefore, ACES improves opportunities for both early detection and response to public health threats.

3.1.3. *Data Security and Privacy*

All data collected for ACES from participating hospitals are stripped of key identifiers (i.e., name, health card number, residential address, and full postal code). The data are nonetheless treated as personal health information under the *Personal Health Information Protection Act* (PHIPA)[16] with steps taken to protect the security and confidentiality of all information. The *ACES Privacy and Confidentiality Charter*[17] outlines the policies, principles, and procedures necessary to meet the intent of PHIPA. Likewise, a *Privacy Impact Assessment*[18] was conducted for ACES in 2014, and regular reviews of policies and procedures to ensure are in place to ensure ACES is in alignment with PHIPA and other applicable privacy legislation. KFLAPH enters data sharing agreements with all local public health agencies and participating hospitals. Users need to register with ACES and sign a confidentiality agreement (excerpt, Figure 15). These policies and procedures ensure that all health information extracted, stored, and processed using ACES is protected according to robust provincial standards for personal health information.

Figure 15. ACES User Confidentiality Agreement (excerpt)

I agree to:

1. Acquaint myself, and comply, with ACES' policies and procedures governing the collection, use, and protection of ACES Confidential Information;
2. Know and uphold my approved level of access to ACES Confidential Information;
3. Limit requests to access ACES Confidential Information to the minimum required;
4. Use ACES Confidential Information only for the purposes for which it was provided to me;
5. Disclose ACES Confidential Information only to persons who have entered into a confidentiality or non-disclosure agreement with ACES;
6. Securely return or destroy ACES Confidential Information immediately if my relationship with ACES ends and otherwise is requested, in accordance with ACES' instructions;
7. Notify the ACES Project Director, or his/her designate, immediately, and co-operate with ACES, if I receive any external demand for ACES Confidential Information;
8. Immediately report to the ACES Project Director, or his/her designate, any failure, or potential failure, to protect ACES Confidential Information in accordance with ACES policies and procedures or this Confidentiality Agreement, and co-operate with any resulting investigation; and,
9. Return all ACES IT equipment, identification cards, access cards, and keys no later than the last day of my relationship with ACES.

I acknowledge that:

1. My compliance with this Confidentiality Agreement is subject to audit by the ACES Project Director or his/her designate;
2. Failure to protect ACES Confidential Information in accordance with this Confidentiality Agreement may lead to discipline up to and including termination of my relationship with; and,
3. My duty to protect ACES Confidential Information will continue indefinitely.

Source: KM 2020

[15] Syndrome: medically significant categories based on chief complaint or admissions diagnoses. See Appendix B: ACES Syndromes.

[16] Personal Health Information Protection Act, 2004. *ontario.ca/laws/statute/04p03*

[17] Access the charter: *kflaphi.ca/wp-content/uploads/ACES-Privacy-Charter2.pdf*

[18] Access the 2014 Privacy Impact Assessment: *kflaphi.ca/wp-content/uploads/ACES-Privacy-Impact-Assessment.pdf*

3.2. Login Page

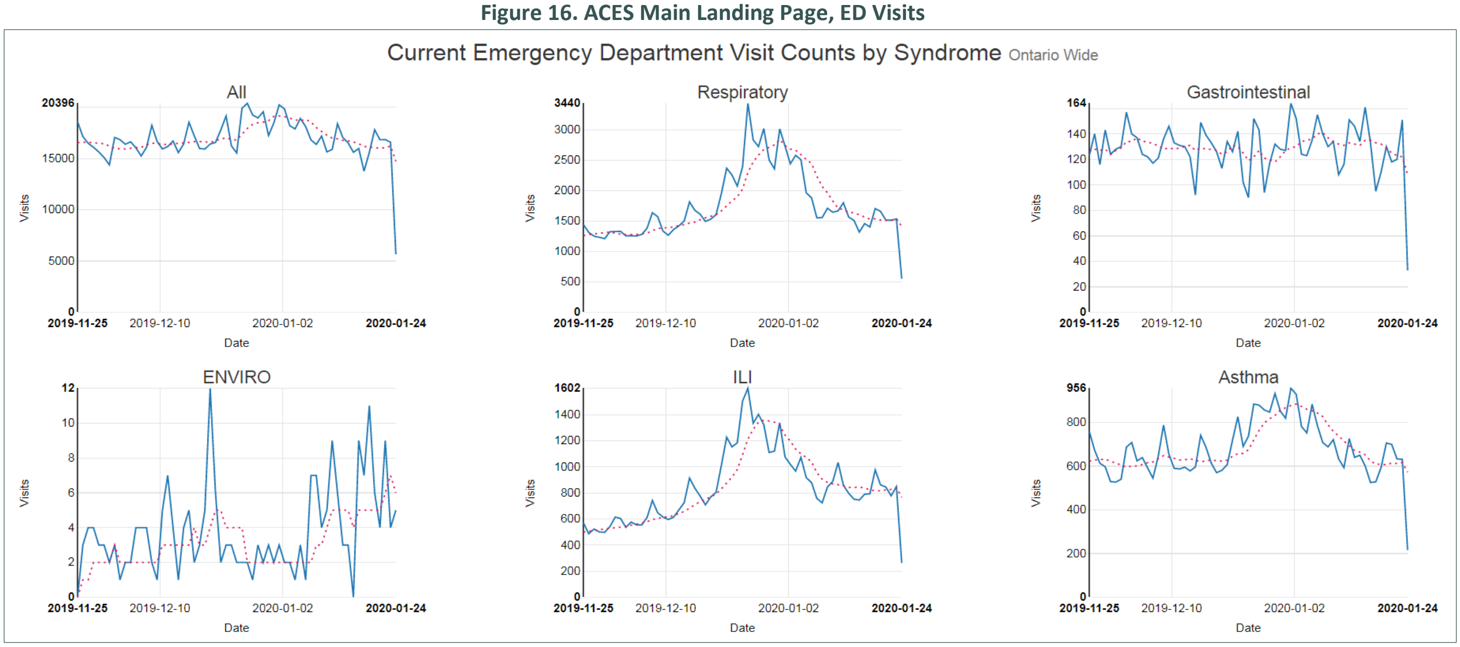
Registered users can access *ACES* at *aces.kflaphi.ca*. Logging in requires both username and password. Users will be given access to the data according to their health agency's data sharing agreement. The user account policy[19] outlines procedures regarding account creation, password management, and account deactivation. Accounts are created for qualifying professionals according to the user account policy and will be deactivated after 90 days of inactivity. Accounts can be reactivated after extended leaves.

3.3. Main Landing Page

Upon logging in, users are directed to the ACES' main landing page. This page provides an overview of current provincial ED visit counts and admission counts for the past 2 months, and current alerts from the past 24 hours. The overview of the provincial ED visits and admissions counts consist of 6 graphs each and are customizable. For example, Figure 16 shows six (6) ED visits graphs including All (i.e., total ED visits), and the syndromes RESP (respiratory), GASTRO (gastrointestinal), ENVIRO (environmental), ILI (influenza-like illness), and AST (Asthma)[20], and Figure 17 shows six (6) admissions graph including All (i.e., total admissions counts) and the syndromes PN (pneumonia), GASTRO, ILI, SEP (sepsis), and MH (mental health)[19]. To customize the contents of the graphs, click on its title and choose a syndrome from the dropdown menu; these changes are saved to the user profile and become the default view for subsequent logins. Below these graphs is a table including current province-wide alerts (Figure 18); a discussion of the methods used to calculate and identify alerts is in Section 2. The display of alerts can be modified using the dropdown menu at the green arrow found at the top right corner; choose from the data elements to be displayed by clicking checkboxes or click on the *groupby* icon (▤) after the data element to display the information grouped by that parameter (Figure 19). ACES' default setting is to display these parameters by date/time. Clicking on the gray arrow again will collapse the options display. Data can be downloaded to a csv formatted spreadsheet by clicking the CSV Export option at the bottom of the alerts table; the csv file will contain information on all alerts for the past 24 hours.

At the top of the page are the main navigation options; each tab is discussed in sequence: 1. **Epicurves**, 2. **Line Listings**, 3. **Resources**, 4. **Maps**, and 5. **Alerts** (Figure 20).

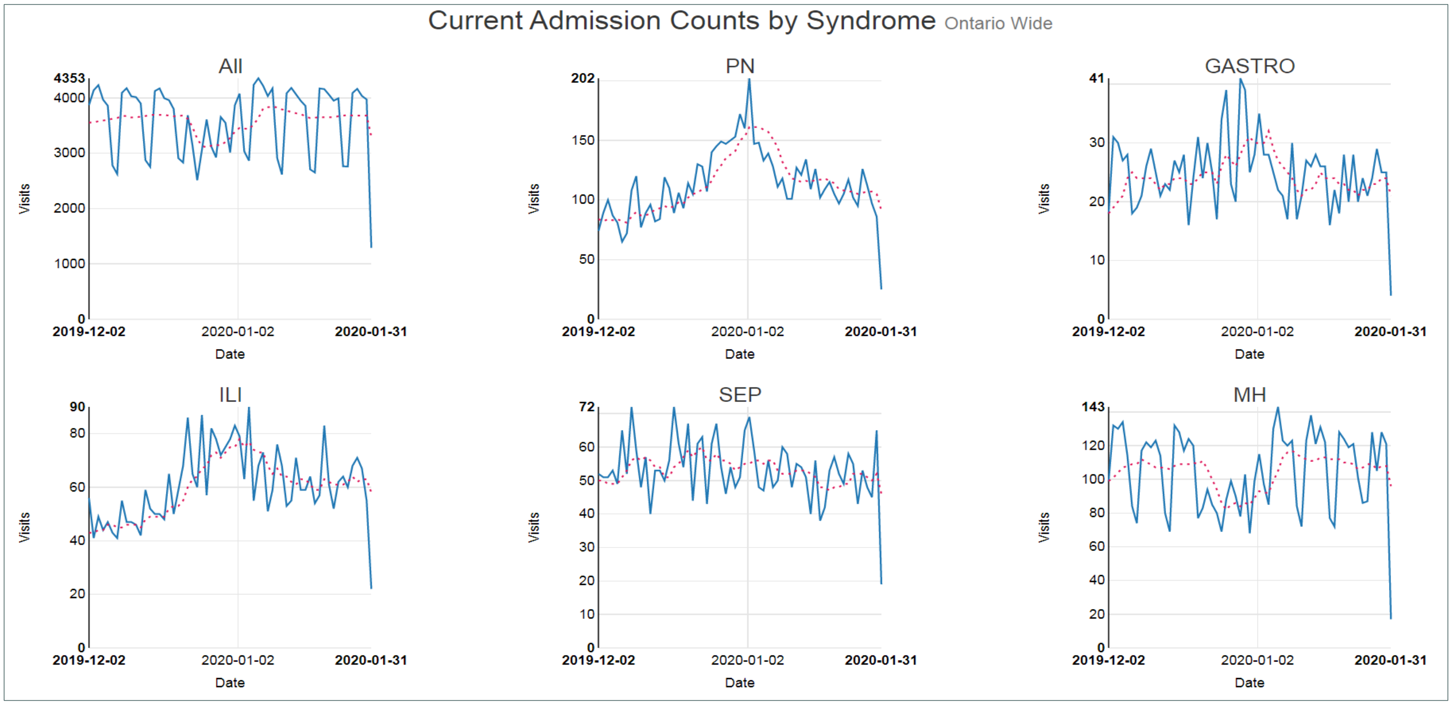
Figure 16. ACES Main Landing Page, ED Visits



Source: KM 2020

[19] Access the ACES Account Management Policy and Procedure: *kflaphi.ca/wp-content/uploads/III40_ACES-User-Accounts.pdf*
[20] See Appendix D for a list of syndromes with descriptions.

Figure 17. ACES Main Landing Page, Admissions Visits



Source: KM 2020

Figure 18. ACES Main Landing Page, Alerts

Current Alerts Ontario Wide

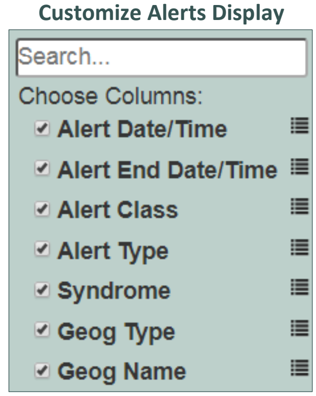
Click arrow below for more options.

Alert Date/Time	Alert End Date/Time	Alert Class	Alert Type	Syndrome
2020-01-31 13:23:00		CUSUM	CUSUM1	COPD
2020-01-31 12:47:00		CUSUM	CUSUM1	TOX
2020-01-31 12:40:00		CUSUM	CUSUM1	ILI
2020-01-31 12:40:00		CUSUM	CUSUM1	RESP
2020-01-31 12:36:00		CUSUM	CUSUM1	VOM
2020-01-31 12:07:00		CUSUM	CUSUM1	RESP
2020-01-31 12:03:00		CUSUM	CUSUM1	GASTRO
2020-01-31 12:01:00	2020-01-31 12:44:00	CUSUM	CUSUM1	RESP
2020-01-31 11:53:00		CUSUM	CUSUM1	VOM
2020-01-31 11:35:57	2020-01-31 12:45:03	CUSUM	CUSUM1	RESP
2020-01-31 11:24:00		CUSUM	CUSUM1	VOM
2020-01-31 11:22:00		CUSUM	CUSUM1	RESP
2020-01-31 11:11:00		SPC	Extreme	MH

Total Items: 125 CSV Export

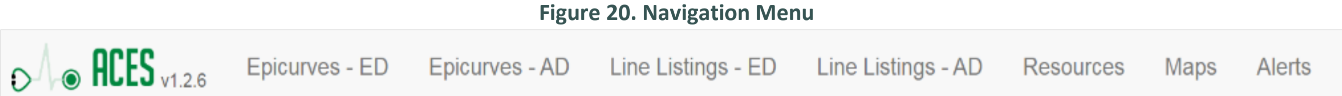
Source: KM 2020

Figure 19. Dropdown Menu to Customize Alerts Display



Source: KM 2020

Figure 20. Navigation Menu



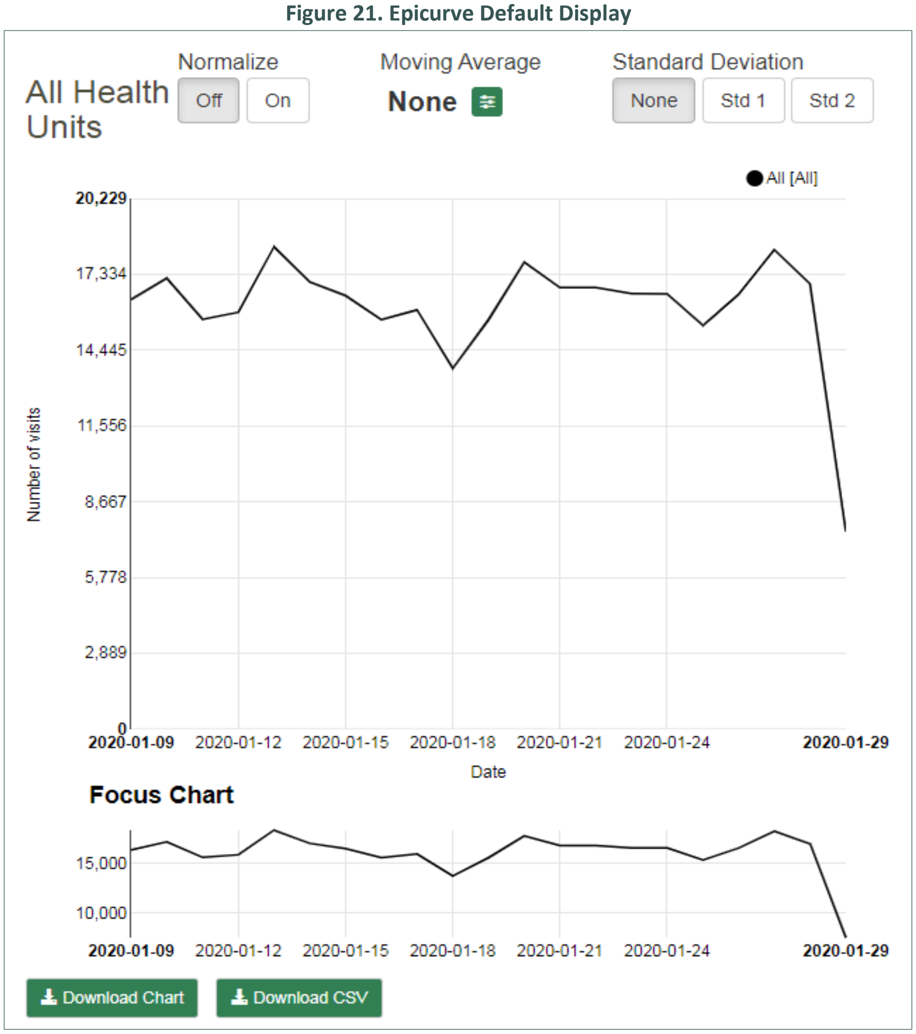
Source: KM 2020

3.4. Epicurves – ED and AD

The two Epicurves tabs have the same functionality, with ED and AD representing ED admissions and inpatient hospital admissions, respectively. Click the tab and a graph loads with total daily counts for the last 21 days for the geography authorized for the account (Figure 21). The graph can be customized to display counts for specific hospitals, dates, by sex or age group, and for syndromes (changing these options will be discussed in the next section). The graph can be downloaded as graphic file or as data in spreadsheet format by clicking Download Chart or Download CSV at the bottom of the graph.

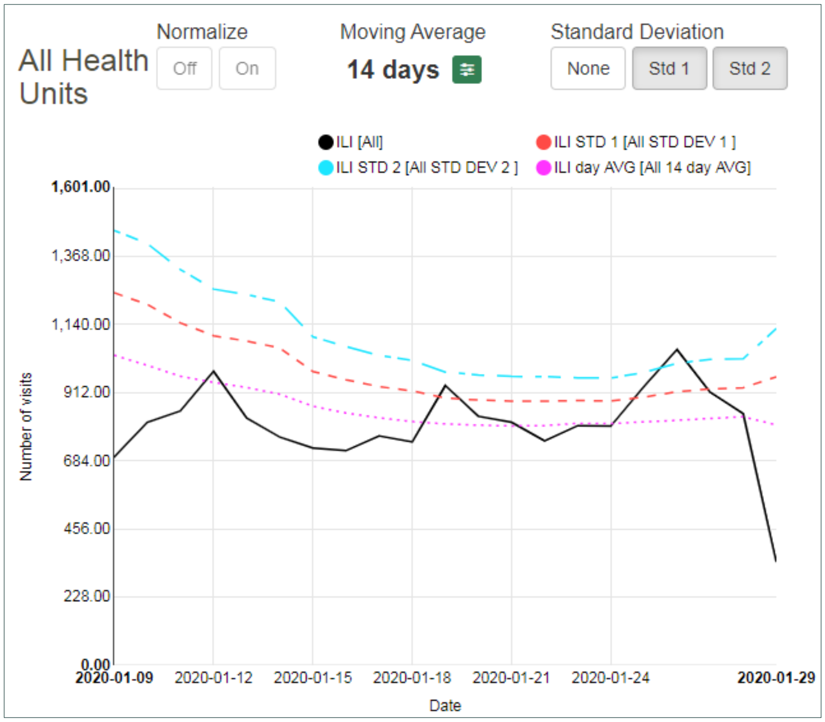
At the top of the graph is clickable options to add descriptive percentage features to the graph. **Normalize** converts counts to a of total counts for display. For example, if a syndrome is chosen from the dropdown menu to the right, click **On** and the daily number of visits are shown as a percentage of total daily visit. **Moving Average** displays a moving average calculate for between 0 and 30 days. **Standard Deviation** calculates variation based on the moving average; if no moving average is specified, standard deviation is based on a 7-day moving average. One standard deviation (**Std 1**) or two standard deviations (**Std 2**) can be displayed (Figure 22). Note that the Normalize feature defaults to **OFF** if the **Moving Average** and/or **Standard Deviation** features are used.

Figure 21. Epicurve Default Display



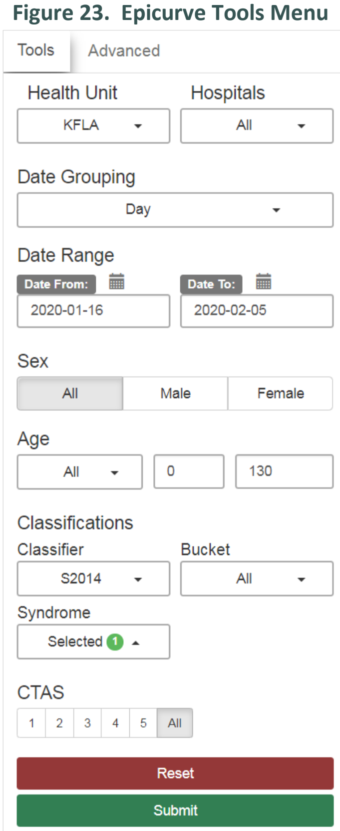
Source: KM 2020

Figure 22. Epicurve for ILI with Statistics Display



Source: KM 2020

Figure 23. Epicurve Tools Menu



Source: KM 2020

There are many options available to customize and optimize the epicurve (Figure 23). Choose each option carefully from the list, including:

- Health Unit and Hospital**:** choose the public health agency and/or hospitals to be displayed. The options available depend on the account holder's data sharing agreement. Hospital users can view their hospital's data and public health agency users can view data from individual and aggregate hospitals within the agency's boundary.
- Date Grouping: choose to view data as aggregate counts by day, week, month, or year (explanation follows).
- **Date Range:** enter a date range or choose Date From and Date To from the drop-down calendars. Choose up to 7 days of data at a time for any date within the hospital's (or region's) historical dataset. Contact *kflaphi@kflapublichealth.ca* to find out when specific hospitals started sending data to ACES. The default data range is past 3 weeks.**Sex:** choose All, Male, or Female. Default is All.
- **Age:** click on the dropdown menu to choose from six options: All, Child (ages 0 to 17), School Child (ages 5 to 17), Adult (ages 18 to 64), Senior (ages 64 to 130), and Adult + Senior (ages 18 to 130). Alternatively, manually input the desired age range. Default is All.
- **Classifications**: choose from the S2014 or S2018 Classifier, specific or multiple syndromes, and Bucket options that include general groupings of syndromes (explanation follows).
- **CTAS[21]:** default setting is **All**.

When all choices for display options are complete, click the Submit button. Reset will return all parameters to default settings.

[21] CTAS: Canadian Triage Acuity Score. See *http://ctas-phctas.ca/*

Date Grouping

The date grouping dropdown menu creates epicurves for aggregate counts displayed by day (default setting), week, month, or year. If week is chosen, the week can start on Sunday or Monday. Regardless which option is chosen, the start date entered in the **Date Range** must reflect that choice and the end date must be for a completed week. Partial weeks are not recognized by the system. Similarly, if graphing by month or year, complete months or years must be included in the date range. Note that if the year grouping is selected, a large amount of data will be displayed, and depending on the syndrome(s) chosen, it may take longer than typically experienced for the epicurve to render and display.

Classifications

The drop-down menu for **Classifier** gives the option to display syndrome data that was classified according to the ACES classifier created in 2014 (ACES Standard Syndromes, S2014) and the 2018 version, S2018. In 2014, former RODS-based EDSS system was replaced with the ACES system, increasing from eight syndromes to over 80 (see current syndroms in Appendix C). The new syndromes were hand classified using almost 35,000 randomly selected visit records. Machine learning drills were used to train the S2104 classifier. Work to improve the classifier began in 2017 to compile all known misclassifications and factor them into a new training data set. The S2018 classifier was trained and all historic ACES data has been reclassified using the new version. The S2014 classifier remains the default until users are comfortable with the 2018 version and until documentation of the differences in the classifiers is completed and shared with users.

For a discussion of how hospital visits are classified into the various syndromes, see Section 2. The **Syndrome** dropdown includes all current ACES syndromes (Appendix C), and the option to choose **All**. The scroll bar on the right is needed to see the full list. Up to five different syndromes can be selected for display. Choosing **Normalize** will display the counts as percentages of total counts. The **Bucket** dropdown menu allows quick customization of the epicurve using pre-defined groupings of syndromes. By selecting a bucket, the syndromes are automatically selected and displayed as separate lines on the epicurve. The current buckets and associated syndromes are in Table 4.

Table 4. Syndromes Included in Current Buckets

Bucket	Syndromes Included
All	All syndromes
Cardiovascular	CAD (coronary artery disease, chest pain) CHF (congestive heart failure) CV (cardiovascular (excludes MI and strokes; includes peripheral vascular disease)
Dermatological Infections	CELL (cellulitis, non-wound infection, non-abscess) DERM (rash, undifferentiated, lesion, wart) NEC (necrotizing fasciitis, severe cellulitis, gangrene)
Environmental Health Effects	AST (asthma, wheeze, difficulty breathing, SOB) COPD (chronic obstructive pulmonary disease) DEHY (dehydration) ENVIRO (heat stroke, heat syncope, heat exhaustion, cold-frost bite, hypothermia) SI (smoke inhalation, chemical, gases)
Health System CQI	CDIFF (c difficile) PO (post op infection or complication)
Major Accident or Injury	ORTHF (fracture, non-hip) ORTHH (fracture of the femur or hip) TRMVC (trauma from a MVC/ATV) TRO (trauma from another means, fall etc.) TRW (gunshot or stab, violence, assault)
Mental Health	MH (mental health) MHS (suicidal ideation, attempt or overdose) SOC (social admission)
Respiratory Infections	BRONCH (bronchiolitis, RSV) CROUP (croup-PIV) ILI (fever, myalgia, undifferentiated flu) PN (pneumonia) RESP (respiratory infection non-croup, non-bronchiolitis)
Toxicity	EOH (alcohol and complications-intoxication, addiction, withdrawal or end organ damage) OPI (opioid intoxication, addiction overdose, withdrawal) TOX (toxicology-not alcohol or opioids, withdrawal, substance abuse, chemical exposure)

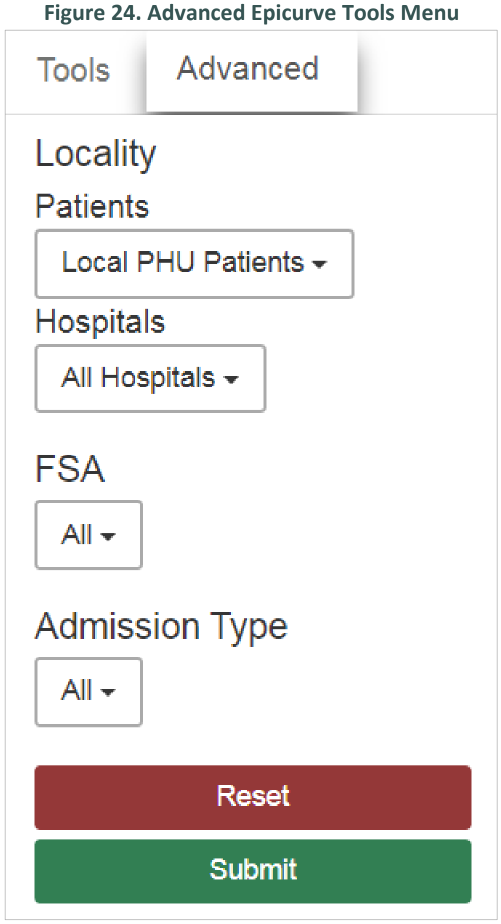
Source: KM 2020

Advanced Display Options

The **Advanced** tab at the top of the options menu shows more choices for optimizing data display (Figure 24) including **Locality**, **FSA**, and **Admission Type**. Locality determines the geography of either the **Patients** or the **Hospitals** displayed; **Local** must be chosen for either patients and/or hospitals. By choosing **Local PHU Patients** from the **Patients** dropdown menu, only patients with residential postal codes from within the regional boundaries of the local public health unit (PHU) will be displayed; **Outside of PHU Patients** displays patients with postal codes outside of the PHU; and **All Patients** displays all patients regardless of residential postal code. Likewise, patients from a specific **Hospital** geography can be displayed: choose **Local PHU Hospitals** from the **Hospital** dropdown menu to display patient records from hospitals within the PHU; select **Outside of PHU Hospitals** for patients in hospitals outside of the local hospitals; and **All Hospitals** for patients in all participating hospitals in Ontario. Note that account users will have access to only those hospitals and PHU regions that are included in their user account agreements; hospital users can view their own hospital data, and PHU staff can view all (participating) hospital(s) within the PHU boundaries. Finally, **FSA** refers to forward sortation area (first three digits of postal code); choose specific FSAs to display patient record with the selected FSA.

A key difference between the tabs **Epicurves – ED** and **Epicurves – AD** is the option to graph inpatients admissions (AD) by **Admission Type**. Two options are available for admission records: **Elective** and **Emergent**. Elective admissions are scheduled visits (Monday to Friday) that usually involve a medical procedure; emergent admissions are unscheduled and can arrive any time. Often, emergent admissions arrive by ambulance, but patients can also be admitted directly from the ED based on the severity of symptoms and treatment needs. The default is to graph both admission types together. When all display options are chosen, click Submit or Reset to clear current selection and start again.

Figure 24. Advanced Epicurve Tools Menu



Source: KM 2020

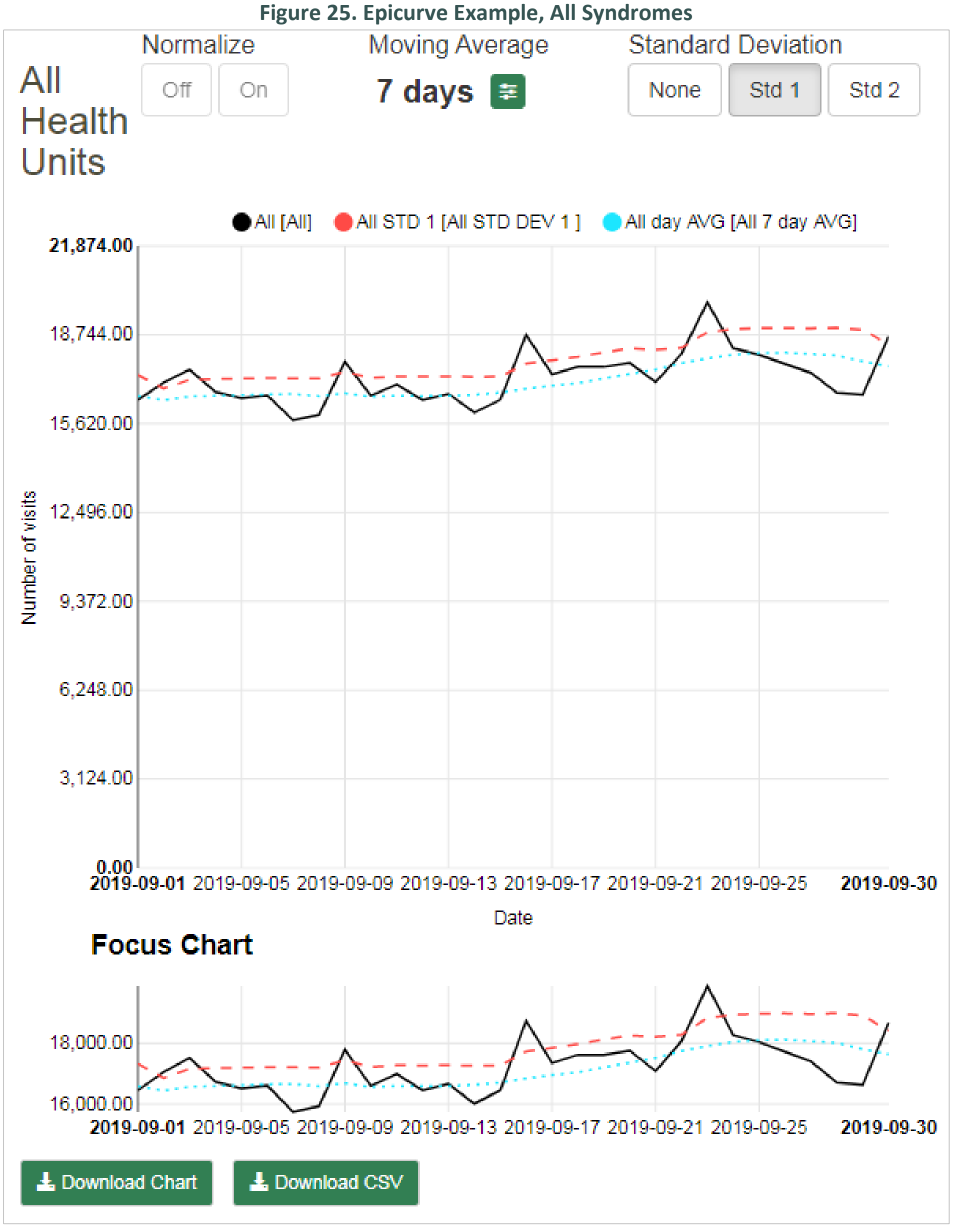
3.4.1. *Creating an Epicurve*

This example shows the steps to create an epicurve in ACES. Log in, select the **Epicurves – ED (or AD)** tab at the top of the page. At the top of the graph, choose **Moving Average, 7 days** and **Std1** (1 standard deviation). These options now appear in the legend and the corresponding lines appear on the graph. Next, select the following options from the **Tools** menu:

- **Health Unit:** choose from choices availables
- Hospitals: All
- Date Grouping: Day
- **Date Range:** 01 September 2019 to 30 September 2019
- **Sex:** All
- **Age:** All
- **Classifications:** Classifier = S2018, Bucket = All, and Syndrome = All
- **CTAS:** All

Click Submit. The resulting epicurve is shown in Figure 25 (each user's display will differ based on account permissions). The solid black line on the epicurve is daily visit counts for the date range selected. The dotted blue line is the seven-day moving average and the dashed red line is the standard deviation. The display statistics can be changed without clicking submit. Next, choose a specific syndrome or change the dates of the data range. Click Submit to display the changes or Reset to clear current selection and start again.

Figure 25. Epicurve Example, All Syndromes

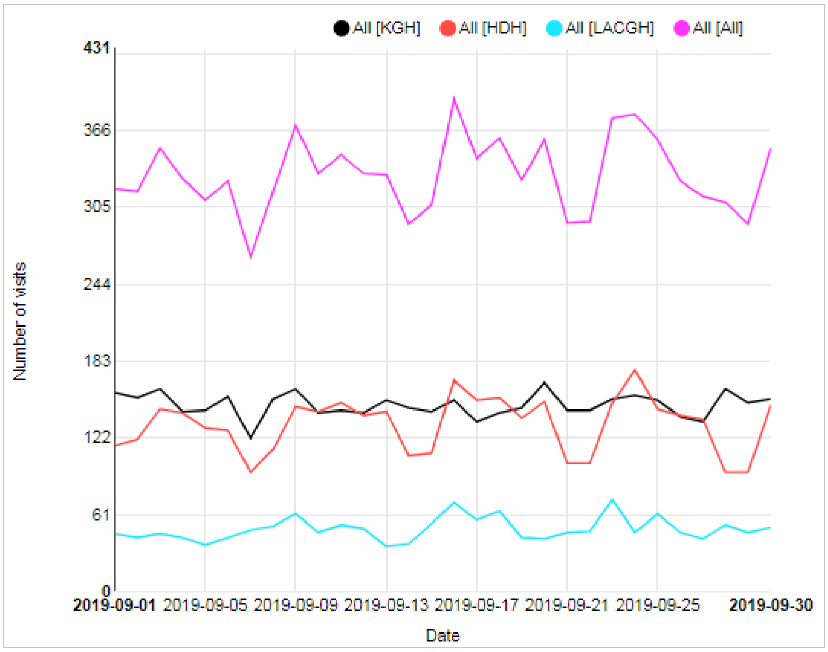


Source: KM 2020

Now, choose all syndromes again and make some different selections in the **Advanced** options tab. Select **Local PHU Patients** and **Local PHU Hospitals** to display data only for local patients that visit local hospitals (where local indicates within the region served by the PHU). Figure 26 shows the resulting epicurve with these options (note each user's accounts will include access to different hospitals/regions). The pink line shows counts for all hospitals combined; the black, red, and blue lines represent hospitals within the KFLAPH region. Statistics can be displayed.

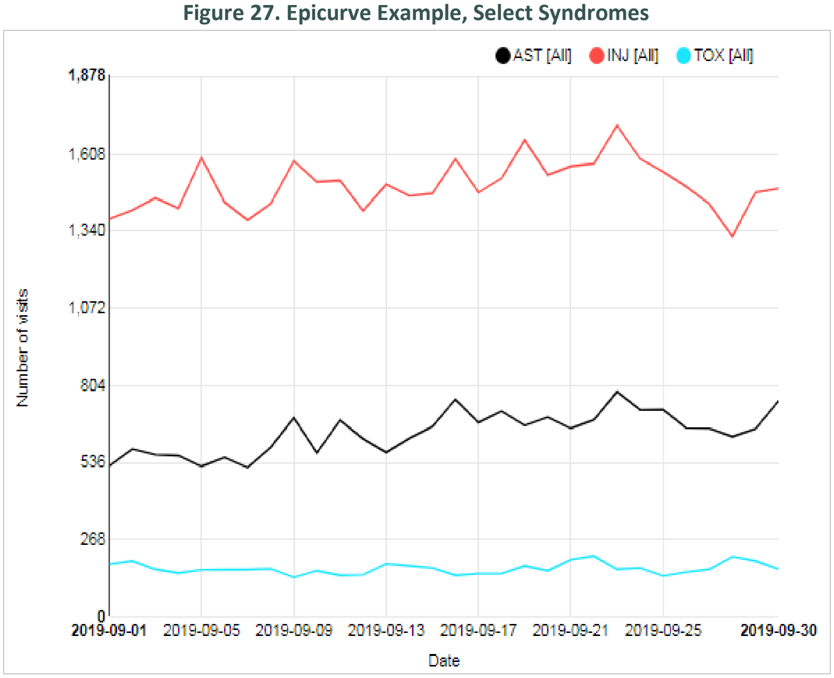
Up to five different syndromes can be displayed simultaneously. In the **Tools** option menu, uncheck All in **Syndrome**, and choose up to 5 syndromes to be displayed. Figure 26 shows the selections from Figure 27 and the syndromes AST (asthma), INJ (injury), and TOX (toxicology); results are for all of Ontario. Again, statistics can be selected for display.

Figure 26. Epicurve Example, By Hospital



Source: KM 2020

Figure 27. Epicurve Example, Select Syndromes



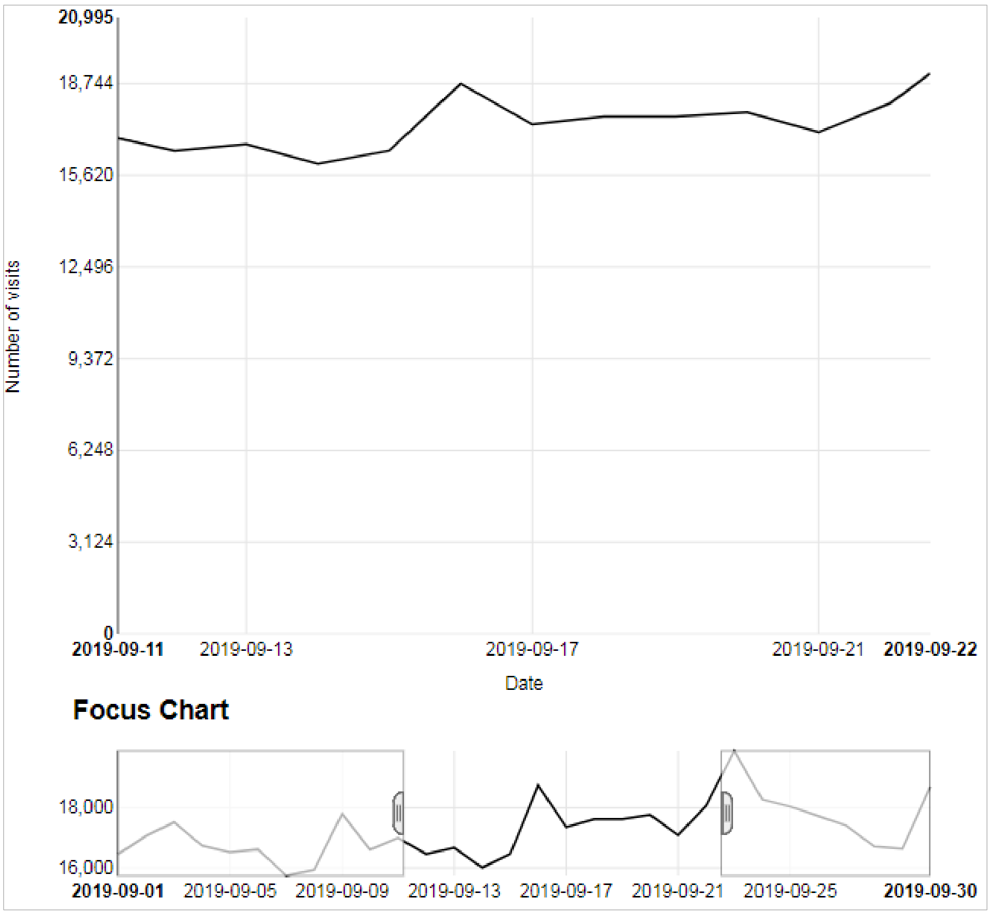
Source: KM 2020

Additional Features

Focus Chart

A helpful feature for data visualization and exploration is located below the epicurve: **Focus Chart**. It enables a narrower timeline to be displayed without submitting a new date range. Move the cursor over the focus chart and it becomes a large cross; click on a desired start time and hold the mouse button while sliding it across the chart to create a window that zooms in on that time selection. The window selection can then be slid back and forth to widen or narrow the date range with arrows that appear at the start and finish of the selection; the time range chosen will be displayed in the larger epicurve above the **Focus Chart** (Figure 28).

Figure 28. Focus Chart



Source: KM 2020

Data Point Display

Hover the cursor over a point on any of the lines on the epicurve (i.e., visits, admissions, moving average, or standard deviation). A box opens with the date and visit count for that data point. Click a data point on the visit count line and a window opens with line listings for that day. Line listings are discussed in following sections.

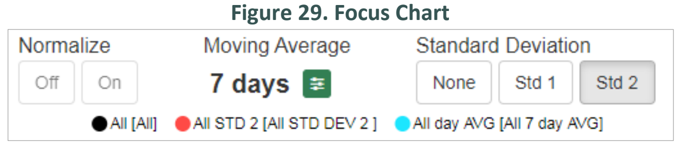
Download Chart

In the bottom left corner of the epicurve page (Figure 25), choose Download Chart to download the epicurve as a Portable Network Graphics (PNG) image file. To download the corresponding numerical data, click Download CSV. These options are available for account holders to share data with colleagues or local stakeholders and is subject to the ACES user account agreement. Only epicurves that display non-identifiable data can be shared.

Epicurve Legend

The legend for a typical epicurve is shown in Figure 29: any of the colored legend symbols can be clicked on and off as needed, removing the entire line from the epicurve. When the statistic is on, the legend symbol is filled; when the statistic is turned off, the symbol is unfilled.

Figure 29. Focus Chart



Source: KM 2020

3.5. Line Listings – ED and AD

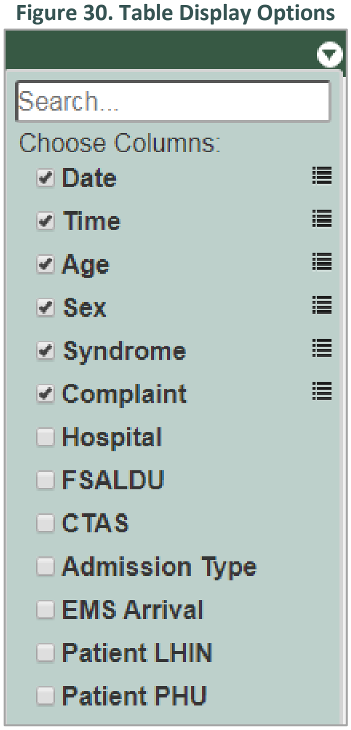
ACES displays ED visits or inpatient admissions (AD) as a textual list of deidentified patient visits with the standard patient information that is received directly from hospitals (i.e., date, time, admission type, age, sex, FSALDU (postal code), hospital, chief complaint or reason for admission, CTAS[22], and arrival by EMS). The tabs **Line Listings – ED** or **Line Listings – AD** displays the most recent data as individual ED visits or admissions in descending chron-ological order for the past two days. The line listing display can be customized using by clicking the green arrow at the top right corner of the line listings table (Figure 30). Click the *groupby* icon (☰) following each data element to display the patient data by that parameter. Note that the *groupby* icon appears beside all options when they are selected. The line listings table has similar features to that of a Microsoft Excel spreadsheet: click on any of the columns to sort the data in ascending or descending order (by date, value, or alphabetical order).

3.5.1. *Tools Menu*

The tool menu to the right of the Line Listings table includes similar options as the **Epicurves Tools** menu discussed above, except the **Date Grouping** option is not available for line listings (Figure 31). As before, select the options for display and click Submit and Reset to return all options to their default settings. Each option is described in the following (also, see discussion of these options in **3.4. Epicurves – ED and AD**):

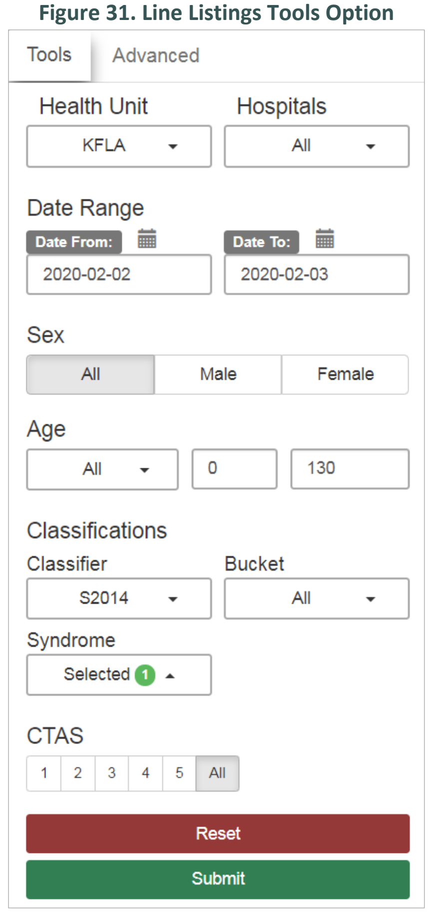
- Health Unit **and** Hospitals: choose from the dropdown list (default setting is All).
- Date Range: enter dates manually or click on the dropdown calendars (default setting displays the past 3 weeks).
- Sex: default is All.
- Age: choose from dropdown options or fill in manually (default is All). See Epicurves – ED and AD for explanation of the age classes.
- Classification**s:** choose the Classifier (S2014 or S2018) and groups of related syndromes from Bucket or up to five specific syndromes from Syndrome dropdown menu. See Epicurves – ED and AD for explanation of classifications menu.
- CTAS[22]**:** default is **All**.

Figure 30. Table Display Options



Source: KM 2020

Figure 31. Line Listings Tools Option



Source: KM 2020

[22] CTAS: Canadian Triage Acuity Score. See *http://ctas-phctas.ca/*

3.5.2. *Advanced Line Listings Options*

The Advanced tab (Figure 32) includes options regarding the **Locality** (or geography) of either **Patients** or **Hospitals**. From the **Patients** dropdown menu, Choose **Local PHU Patients** only patients with postal codes located within the local public health agency's geographical boundaries; choose **Outside of PHU Patients** to display patients from outside the regions that are accessing local/regional hospitals. Likewise, from the **Hospitals** dropdown menu, choose **Local PHU Hospitals** to display patients that are using the hospitals within the local public health agency's jurisdiction or choose **Outside of PHU Hospitals** to display patients from the local are accessing hospitals (reporting to ACES) that are outside of the region. When all display options are chosen, click Submit or Reset to return all of the options to default settings. When viewing the **Line Listings - AD** tab, the **Advanced** has the added option to filter by **Admissions Type**: **Elective** vs **Emergent**. Note that the extent of options shown will depend on the data sharing agreement associated with the user account and *local* must be used for one of the options.

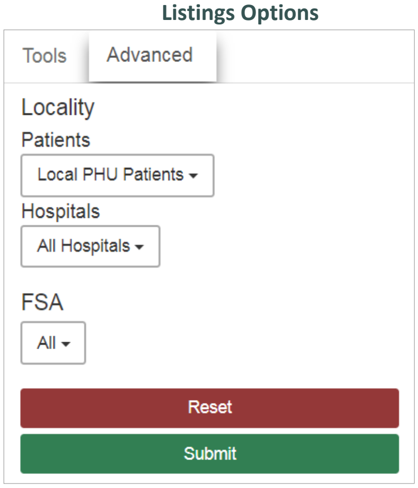
3.5.3. *Viewing an Individual Line Listing*

To view an indivual record, place the cursor anywhere on the line listing of the record and click—the full record will open as a separate window. Tabs at the top of the window are for **Details**, **Alerts**, and **Metadata**. The **Details** tab includes the following information regarding the selected record:

- **Hospital information:** hospital, hospital public health agency (PHU), and hospital LHIN.
- **Admission information:** date, time, day of week, week of year.
- **Triage information:** CTAS, arrival by EMS[23], and FRI[24].
- **Patient demographics:** 3-character postal code, county, municipality, LPHA, CSD, FSA, gender and age.
- **Chief complaint:** text from triage record.
- **Most likely syndromes:** classification statistics using S2014 and S2018 classifiers (explanation follows).

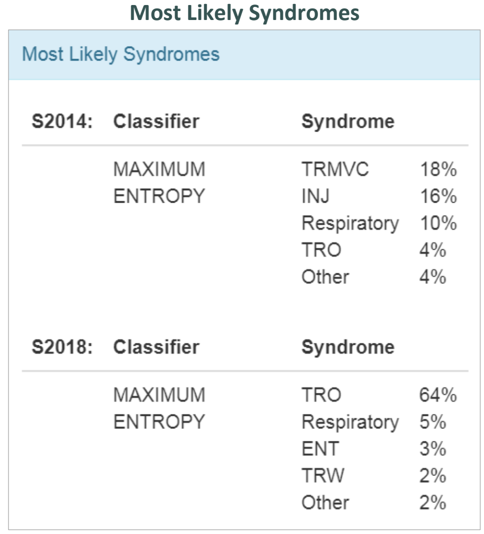
The process to classify each patient record into a medically-relevant syndrome is desribed in Section 2. Briefly, natural language processing methods are used to classify each record according to the words/phrases in the chief complaint/reason for admission. The maximum entropy (ME) algorithm developed for ACES in 2014 (S2014) was updated in 2018 (S2018)—the results for both of these classifiers are summarized on the **Details** tab, **Most Likely Syndromes** (Figure 33). If a problem with the classification of a patient record is suspected, the results shown on this tab should be consulted before contacting the ACES team as it may reveal a secondary syndrome that may be more appropriate for the case. For example, the percentage likelihood is shown for five different syndromes using the S2014 and S2018 classifiers for a patient visit is shown (Figure 32, chief complaint is "nasal trauma"). The S2018 classifier may be more appropriate for this patient's visit (i.e., TRMVC is trauma from motor vehicle collision and TRO is trauma from other means); however, the symptoms may also indicate a respiratory ailment.

Figure 32. Advanced Line Listings Options



Source: KM 2020

Figure 33. Individual Line Listing: Most Likely Syndromes


Most Likely Syndromes

	Classifier	Syndrome	
S2014:	MAXIMUM ENTROPY	TRMVC	18%
		INJ	16%
		Respiratory	10%
		TRO	4%
		Other	4%
S2018:	MAXIMUM ENTROPY	TRO	64%
		Respiratory	5%
		ENT	3%
		TRW	2%
		Other	2%

Source: KM 2020

[23] Arrival by emergency medical services (EMS): if TRUE, the patient arrived by ambulance, if FALSE, the patient did not arrive by ambulance.
[24] Febrile Respiratory Illness: The FRI screening tool was introduced during the SARS outbreak in 2003 to identify SARS cases using a standard series of questions regarding symptoms in the last 24 hours.

3.5.4. *Additional Features*

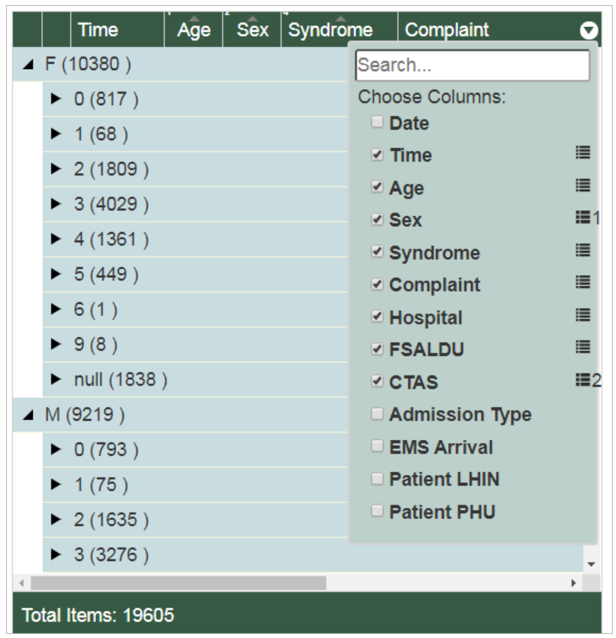
Groupby **Function**

The use of the *groupby* function (*groupby* icon, ▤) was briefly discussed the previous sections—its full functionality with the line listings tabs can provide more flexibility for displaying data. Click on the small downward facing arrow located in the last column heading of the line listing table, then click on one or more of the *groupby* icon(s) to the right of each column element to group the data by the chosen parameter(s) (see Figure 29). For example, Figure 33 shows a line listing table display with **Sex** and then **CTAS** selected. The numbers "1" and "2" after the *groupby* icon indicate the order of grouping. The line listings of patient visits for the past 24 hours are displayed, grouped first by sex and then by CTAS[25], a measure of acuity ranging from 1 (most acute) to 5 (least acute). Of the 19,605 ED visits, 10,380 are female and 9,219 are male; of the visits by females, 4,209 are for CTAS 3 (i.e., moderate acuity). Each of the summarized parameters can then be clicked to display individual patient visits as line listings. Use the *groupby* function to display the line listings by any of the parameters included according to data mining requirements.

Search Function

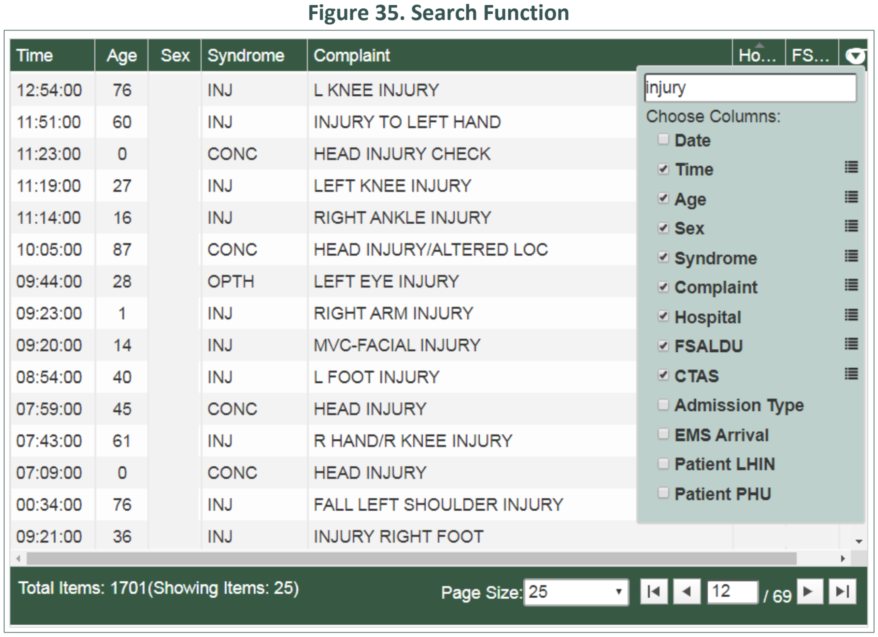
A final feature that is useful for sorting data is the search function found at the top of the *groupby* dropdown menu: the search box enables users to type in key words to identify line listings containing those words. The search function may be useful when investigating the occurrence of a word that may not be classified to a specific syndrome. For example, the line listings shown in Figure 34 are the results of a search for "injury": of the 1,701 total results, a sampling are shown highlighting the different possible syndromes with the text of the chief complaint containing the word "injury". These include INJ (injury), CONC (concussion), and OPTH (ophthalmologic). If the investigation is looking for injuries in general, concussions and eye injuries may need to be collated in addition to patient visits classified as INJ. This search feature is best used for uncommon words or new emerging threats that may not be included in the current natural language classification schema (i.e., S2014 or S2018).

Figure 34. Individual Line Listing: groupby Function



Source: KM 2020

Figure 35. Search Function



Time	Age	Sex	Syndrome	Complaint	Ho...	FS...
12:54:00	76		INJ	L KNEE INJURY		
11:51:00	60		INJ	INJURY TO LEFT HAND		
11:23:00	0		CONC	HEAD INJURY CHECK		
11:19:00	27		INJ	LEFT KNEE INJURY		
11:14:00	16		INJ	RIGHT ANKLE INJURY		
10:05:00	87		CONC	HEAD INJURY/ALTERED LOC		
09:44:00	28		OPTH	LEFT EYE INJURY		
09:23:00	1		INJ	RIGHT ARM INJURY		
09:20:00	14		INJ	MVC-FACIAL INJURY		
08:54:00	40		INJ	L FOOT INJURY		
07:59:00	45		CONC	HEAD INJURY		
07:43:00	61		INJ	R HAND/R KNEE INJURY		
07:09:00	0		CONC	HEAD INJURY		
00:34:00	76		INJ	FALL LEFT SHOULDER INJURY		
09:21:00	36		INJ	INJURY RIGHT FOOT		

Source: KM 2020

[25] CTAS: Canadian Triage Acuity Score. See *http://ctas-phctas.ca/*

3.6. Resources

The **Resources** tab provides information for ACES users from other provincial databases to enable direct comparison with ACES data. Choose from **Influenza** or **Opioid** from the dropdown menu at the right of the screen. The data shown are from CIHI's databases for emergency department visits (NACRS) or hospital admissions (DAD).

3.6.1. *Influenza Resources*

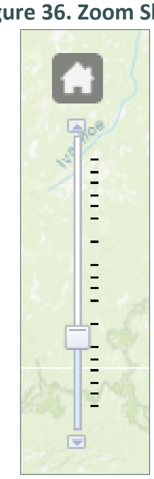
The data included under the Influenza dropdown are 4 tables of data compiled by the Ministry of Health from the NACRS and DAD databases on a monthly basis. These data are made available by the Ministry in response to the lack of morbidity and mortality data that can be accessed in a timely manner during influenza season. These data are usually not available until several months later, but the Ministry is making these data available as they are submitted for enhanced surveillance purposes. Patient visits with ICD-10 codes J9 (*influenza due to certain identified influenza virus*), J10 (*influenza due to other identified influenza virus*), and J11 (*influenza, virus not identifed*) are extracted on the 15th business day of each month and these are formatted and published on this page. The data are presented as unsuppressed counts with the privacy protection of the security measures in place for ACES user agreements. These data are presented at a higher level of aggregation with suppression of cell counts under five on the public-facing ILI Mapper (*mapper.kflaphi.ca/ ilimapper/*). The four tables included are hospital visits, admissions, and deaths among confirmed[26] influenza cases by 1. age range and 2. public health agency for the most recent season, and hospital visits, admissions, and deaths among suspected[27] influenza cases by 3. age range and 4. public health agency for the most recent season.

3.6.2. *Opioid Resources*

The **Opioid** tab provides supplemental data regarding laboratory confirmed opioid overdoses for comparison to syndromes related to monitoring opioid overdose, including OPI (opioid intoxication, addiction overdose, withdrawal) and TOX (toxicology-not alcohol or opioids, withdrawal, substance abuse, chemical exposure). The resource is comprised of two graphs using data released by CIHI for opioid overdose tracking compiled from the NACRS dataset. Provincial aggregate data are shown as 1. counts of opioid overdoses by intent type (intentional, accidental, therapeutic, unknown, and total) and 2. percentages of overdoses by age group. The graphs are updated as data are released by CIHI and therefore the daily counts and percentages shown are subject to change as more information is made available.

3.7. Maps

Figure 36. Zoom Slider



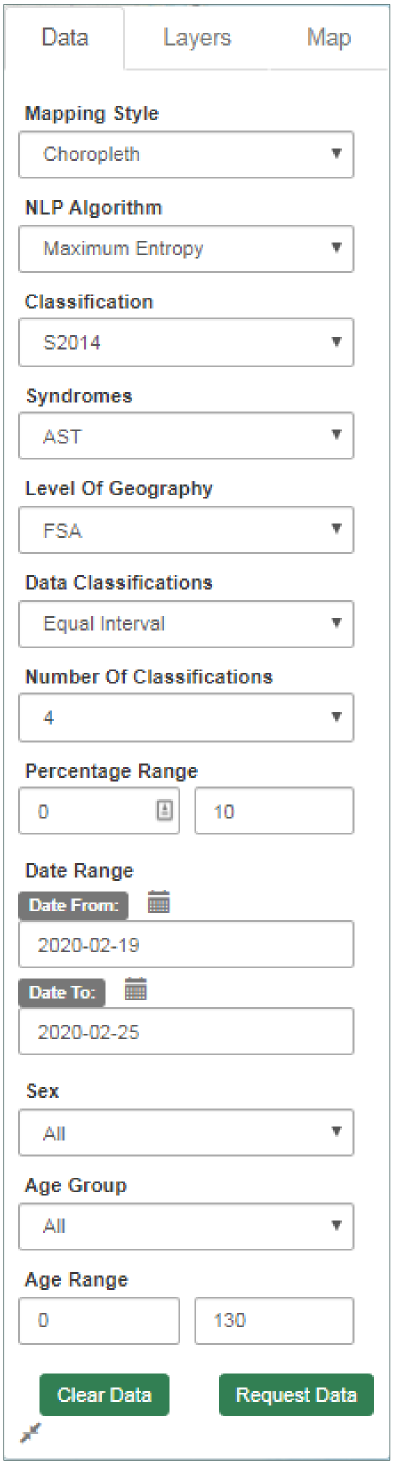
Source: KM 2020

The objective of the **Maps** tab is to enable visual examination of the spatial distribution of acute care hospital visits. Click the **Maps** tab and a map of Ontario appears—to move the map, click and drag the cursor or zoom in or out with the mouse's scroll wheel. At the top left of the map, zoom in or out by moving the slider or return to default view settings by clicking the house symbol (Figure 36). At the bottom right of the map, the location displayed is indicated on a large-scale map. Only data from Ontario hospitals that are actively sharing data with ACES will be displayed on the map. Presently, only ED visits are displayed (i.e., no admissions data are displayed). The main features of the map are customized using the tabs displayed on the right side of the screen (Figure 37). Each tab and its options are described in the following sections. NOTE: only ED visit data is currently available for use with the **Maps** tab.

[26] Include patient visits with ICD-10 codes J9 (*influenza due to certain identified influenza virus*) and J10 (*influenza due to other identified influenza virus*).

[27] Include patient visits with ICD-10 code J11 (*influenza, virus not identifed*).

Figure 37. Map Options, Data Tab



Source: KM 2020

3.7.1. *Map Options – Data Tab*

The main options for displaying data on the map are found in the **Data** tab accessible at the top of the options menu on the right of the map. In the bottom right corner of the tab is an arrow to reduce or expand the menu. For data options to be displayed, choose from each option and then click Request Data; there is no default data display. Each choice is described below.

Mapping Style

Choose between **Choropleth** or **Proportional Symbols** to display the data. **Choropleth** displays the percentage of ED visits for a specific syndrome for each region by variation in colour. **Proportional Symbols** displays the percentage of ED visits for a specific syndrome as a proportionally-sized markers. Both styles are shown for comparison in Figures 38 and 39 at the public health agency geography. Both maps display the same data; legends are shown at the bottom left of each map. The small arrow in the top right corner of the legend that can be used to reduce or expand the size of the legend.

For both mapping styles, move the cursor over a specific region including the name of the level of geography (i.e., the name of the public health agency or county, or the FSA), the total number reveal a pop-up box with details regarding that region of syndrome visits, the total number of ED visits, and the percentage of syndrome visits in relation to total visits. Note: for **Proportional Symbols**, place the cursor over the marker to reveal details.

NLP Algorithm

The dropdown menu default is to the **Maximum Entropy** classifier and is currently the only option available. See **Section 2. Natural Language Processing for Syndrome Classification** for a discussion of natural language processing algorithms for classification in ACES.

Classification

The **Classification** dropdown menu includes two options: **S2014** or **S2018** (default is **S2014**). A discussion of the difference between the classifiers is found in **Section 3. 1. Epicurves, ED and AD. Classifications**. Briefly, the original ACES Standard Syndromes classfier, **S2014** that was developed in 2014 was updated in 2018 (ACES Standard Syndromes classfier, **S2018**).

Syndromes

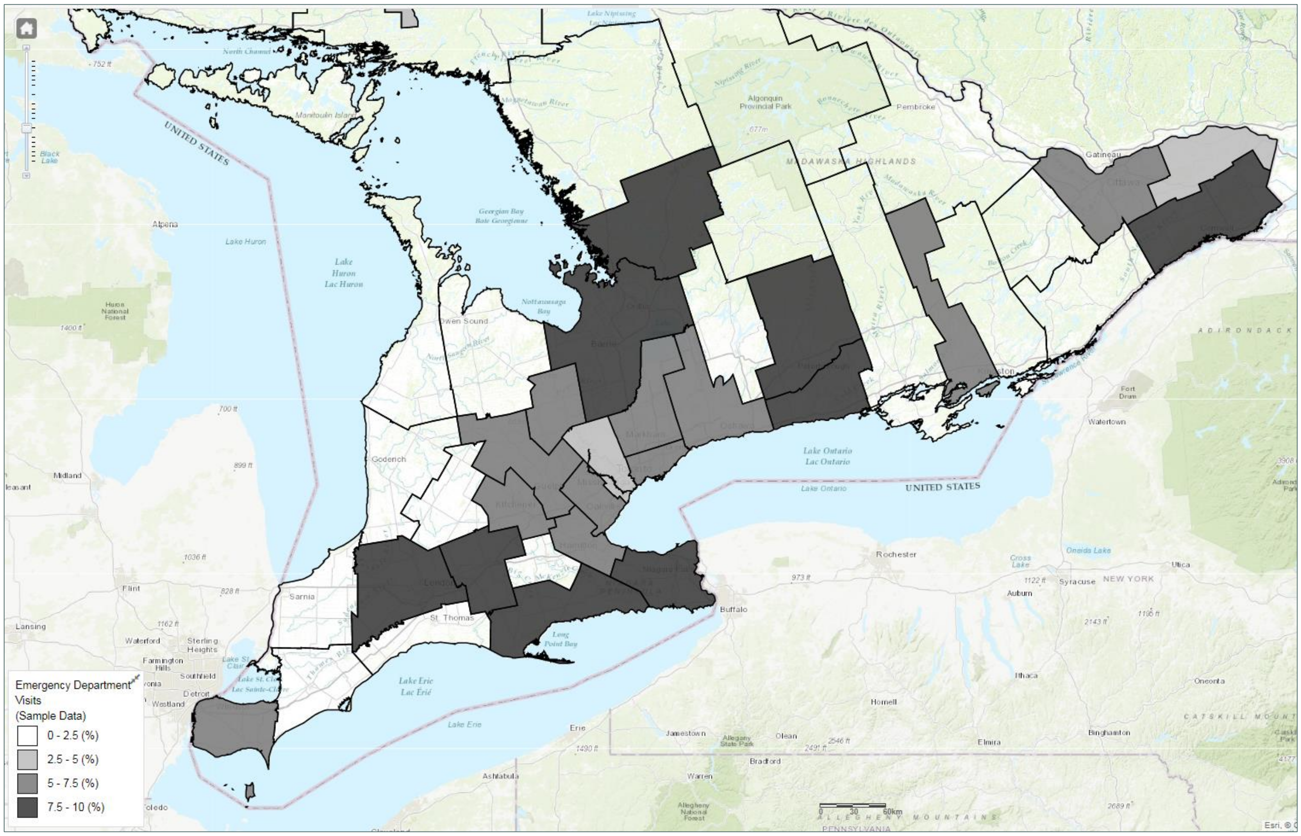
All current ACES syndromes are available in the dropdown manu. See **Appendix C** for descriptions of each syndrome.

Level of Geography

Four choices for geography are included in the dropdown manu: 1. FSA. (first three characters of postal code), 2. county, 3. PHU (local public health agency), and 4. LHIN (local health integration network)[28].

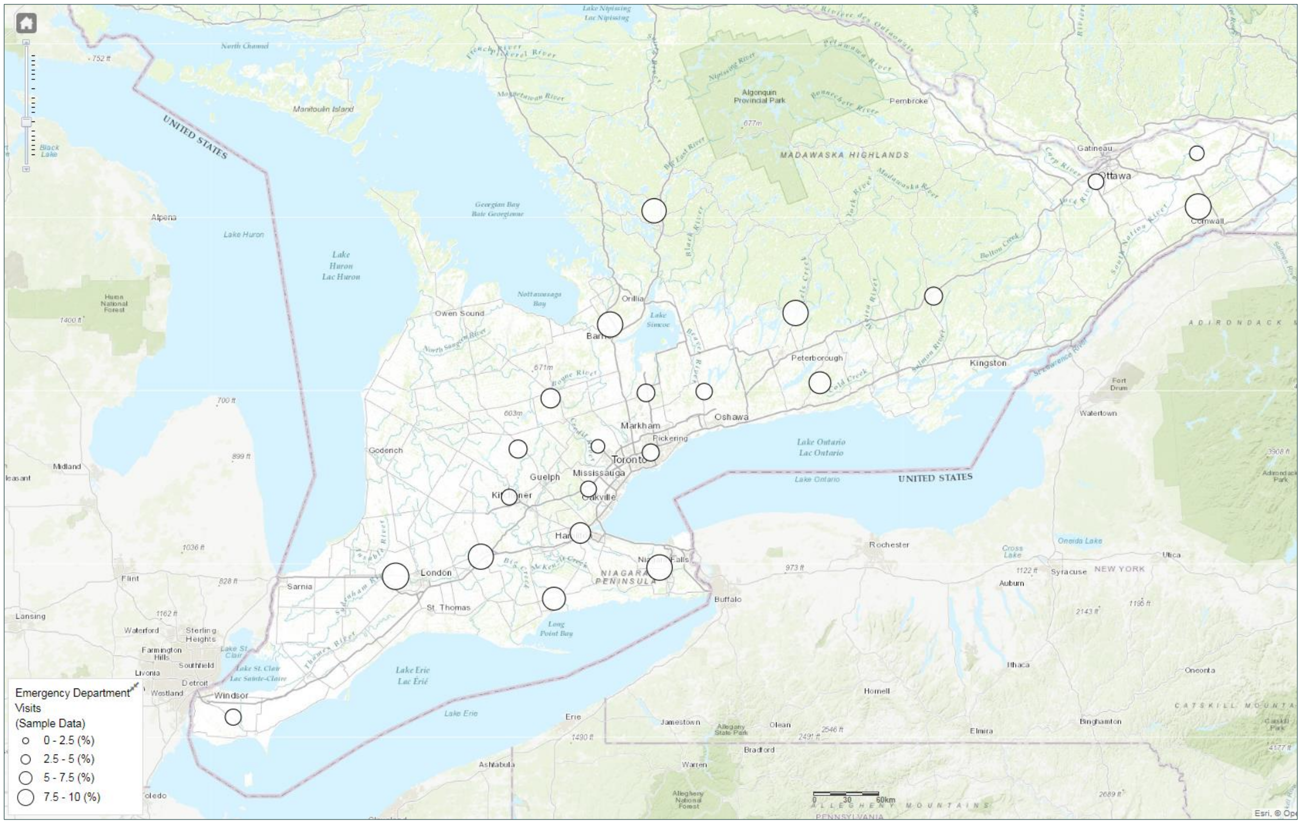
[28] As of publication, the modernization/restructuring of Ontario's healthcare ministries is in progress. Although LHINs are to be restructured, the processes and final geographical boundaries towards updates for local healthcare management are currently under review and will be updated as available.

Figure 38. Mapping Style, Chloropleth



Source: KM 2020

Figure 39. Mapping Style, Proportional Symbols



Source: KM 2020

Data Classifications, Number of Classifications, Percentage Range, and Date Range

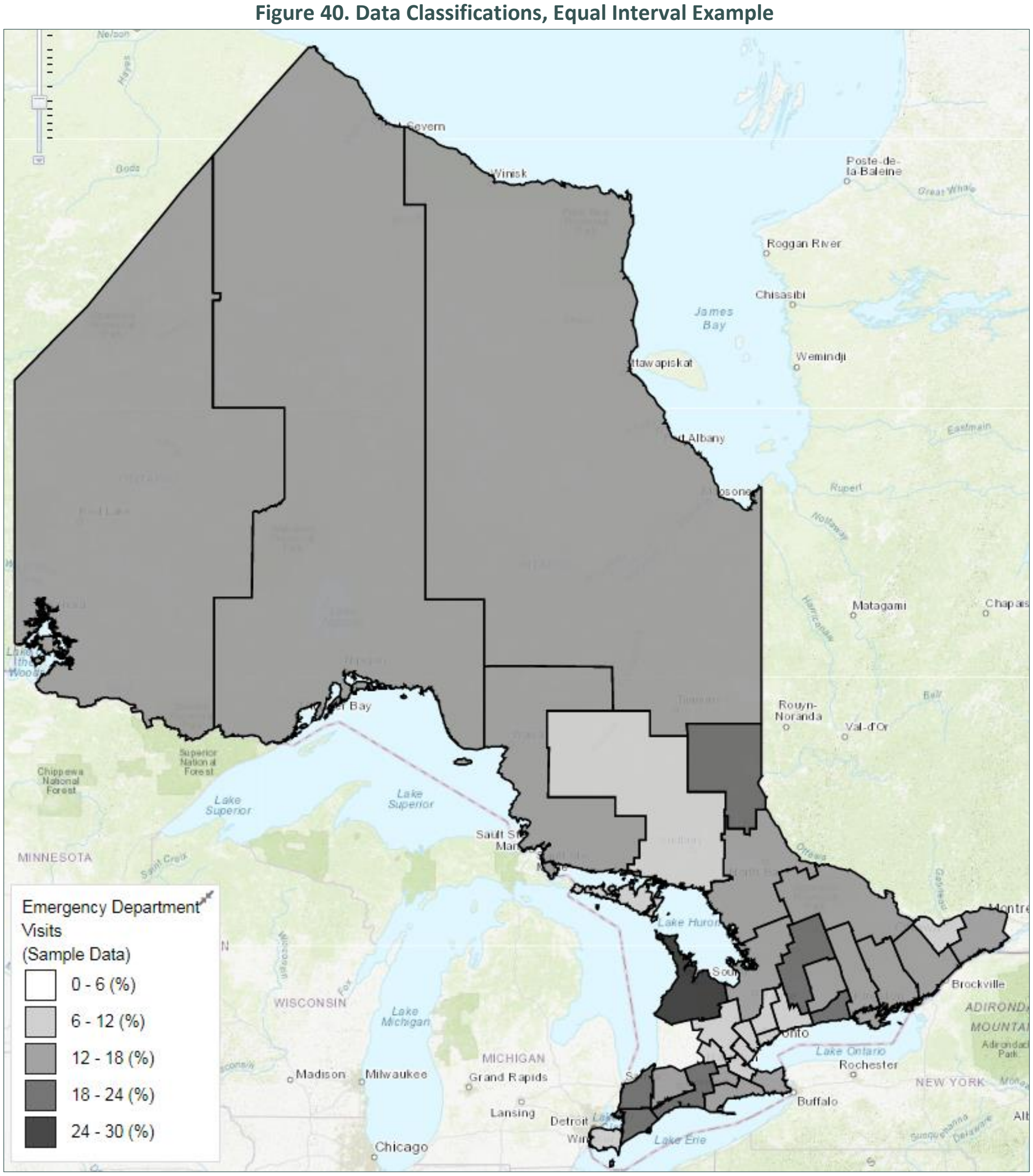
These options work in concert to enable customization of data display. **Data Classifications** are the methods used to display the quantities (or proportions) of hospital visits. With the **Choropleth** mapping style, there are three different ways that the data can be classified:

1. Equal Interval maps the data in equally distributed gradients based on the normalized values, or percentages, for the selected syndrome and geography. The number of gradients is determined by the Number of Classifications chosen. For example, choose the following options:

- **Mapping Style** = **Chloropleth**
- **Syndrome** = **RESP**
- **Level of Geography** = **Public Health Unit**
- **Data Classifications** = **Equal Interval**
- **Number of Classifications** = **5**
- **Percentage Range** = **0** to **30**
- **Date Range** = **2020-01-01** to **2020-01-07**

Figure 40 shows the resulting map of Ontario. There are five percentage ranges of 6% each. Note that when using percentage range, the percentage of total visits that each syndrome represents can vary greatly among different geographies, and a good general understanding of the specific syndrome and its behaviour is recommended for interpretation of the mapping results. For example, RESP syndrome usually represents a high proportion of total visits, however a syndrome such as TICKS is better displayed with a much lower percentange range, such as 0 to 1%.

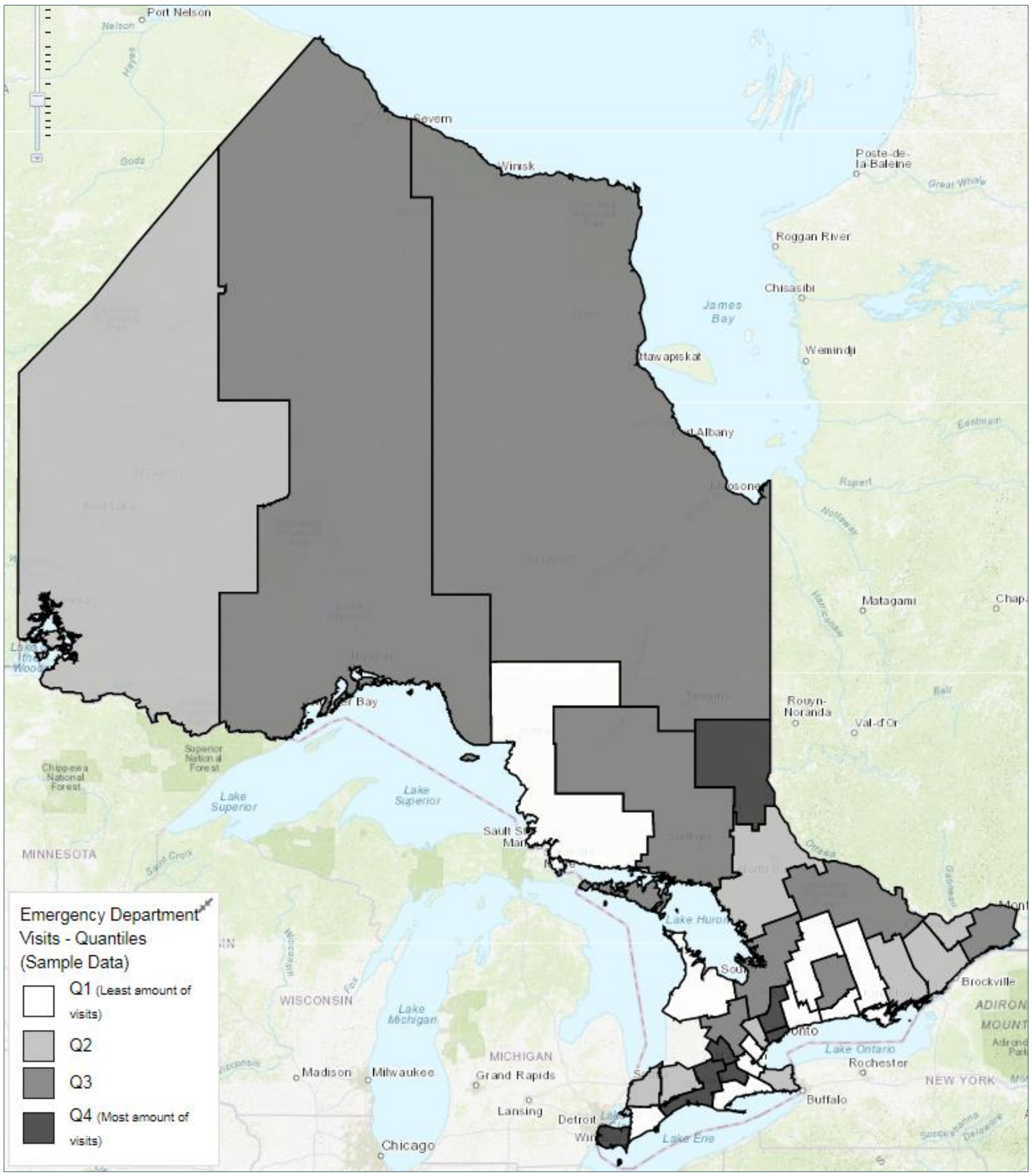
Figure 40. Data Classifications, Equal Interval Example



Source: KM 2020

2. Quantile is a simpler approach: the number of classifications are chosen (i.e, 4, 5, 6, or 10), and the same number of equally sized data subsets are displayed (quartiles, quintiles, sextiles, and deciles, respectively). For example, for the same data request as entered for Figure 40, choose instead **Data Classifcations** = **Quantile** and **Number of Classifications** = **4**. The values for each level of geography are divided into quartiles, Q1 representing the lowest 25% of the values and Q4 the highest 25% (Figure 41). Move the cursor over the map and a pop-up box will appear with the name of the geography, the quantile, the number of ED visits for the syndrome, the total number of ED visits, and the percentage of ED visits for the syndrome.

Figure 41. Data Classifications, Quantile Example



Source: KM 2020

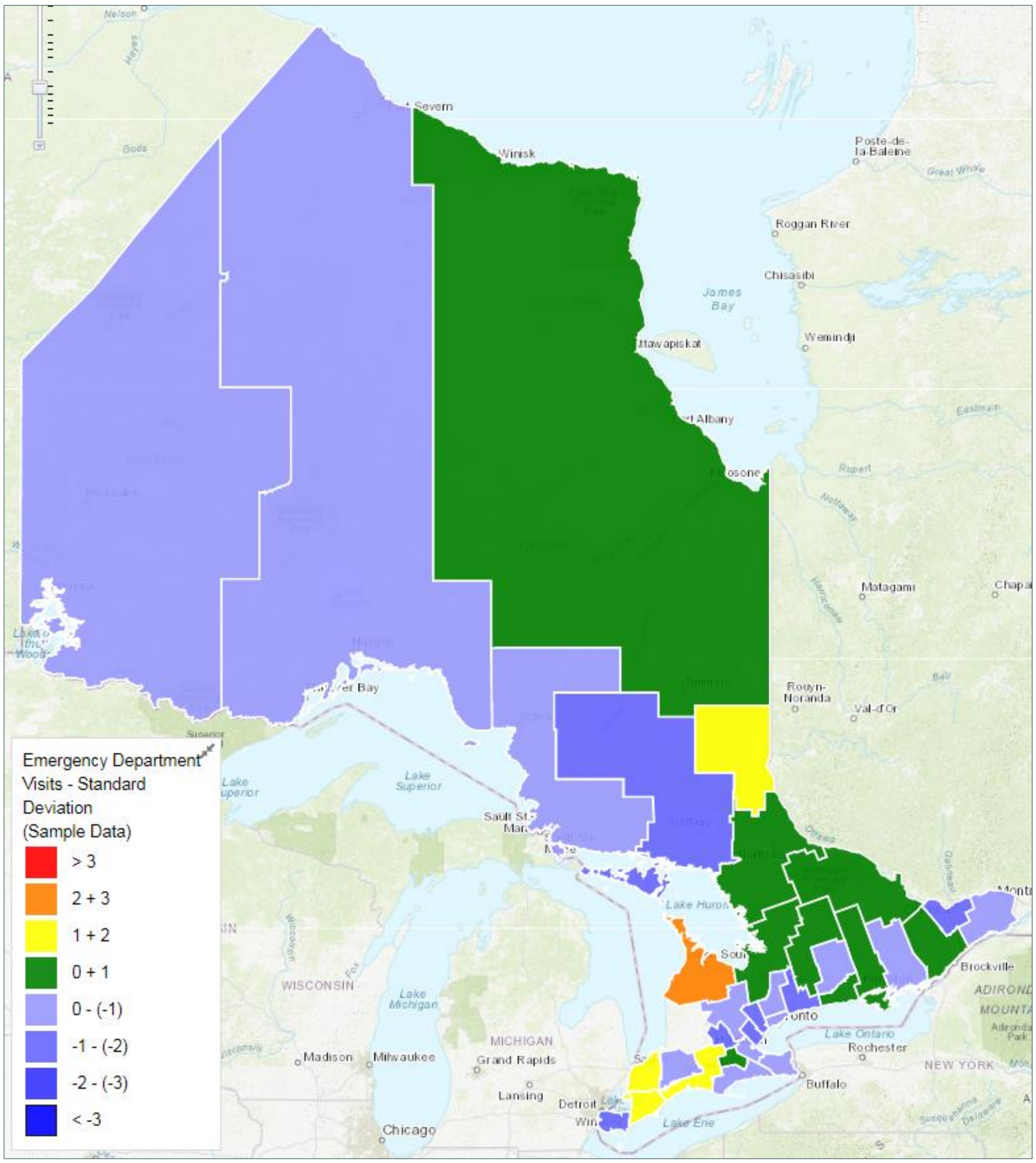
3. **Standard Deviation** displays the data as statistically significant deviations from historic means. For example, Figure 42 shows the same data as Figures 40 and 41, but with **Data Classifcations** = **Standard Deviation** and **Compare to Ontario** = **Yes.** The default option is **No** which displays standard deviation from mean based on the moving average for that specific geography. Choosing **Yes** compares the standard deviation to the moving average of all Ontario. The calculation of standard deviation is directly affected by the number of days chosen in the **Date Range** field. For example, if the date range

is less than or equal to 7 days, the standard deviation is based on the previous 7-day moving average; for date ranges between 8 and 14 days, calculation is based on the previous 14-day moving average; for date ranges between 15 and 28 days, calculation is based on the previous 28-day moving average; and for date ranges greater than 28 days, calculation is based on a 60-day moving average.

Gender, Age Group, and Age Range

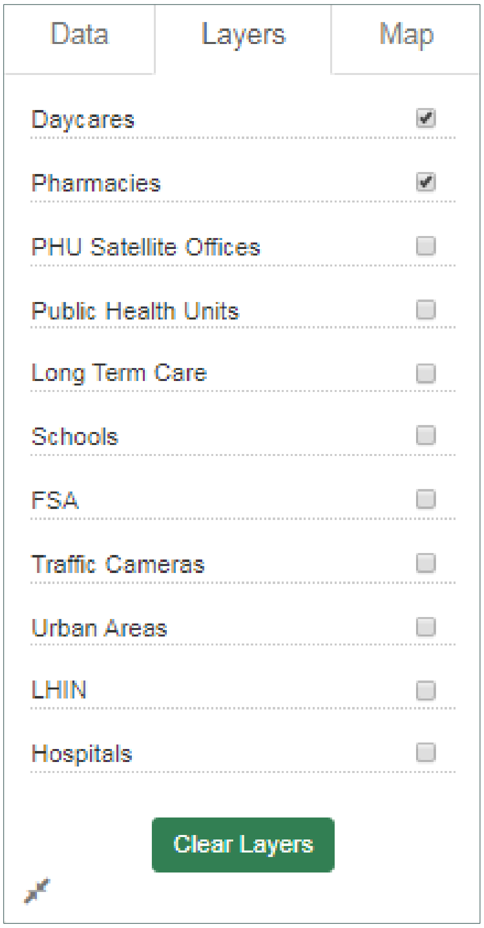
Patient demographics can be display for investigation using the final options available in the **Data** tab menu. Choose from **Sex** (i.e., **All**, **Male**, **Female**), **Age Group** (**Child**, **School Child**, **Adult**, **Senior**, and **Adult + Senior**), and/or Age Range (manually enter minimum and maximum ages for display). Note that the age groups are pre-defined groupings that fill the age range categories automatically. When all options are chosen, click Request Data to generate the map; click Clear Data to revert to the default settings,. Note that large date ranges can be requested but will take longer to display—generally, periods of a month of less will take less time to extract and display.

Figure 42. Data Classifications, Standard Deviation Example



Source: KM 2020

Figure 43. Map Options, Layers Tab



Source: KM 2020

3.7.2. *Map Features – Layers Tab*

The **Layers** tab enables the display of additional information on the map. The current options are shown in Figure 44. Click the box following the feature to display. Note that multiple layers may be displayed but the map may become cluttered; click Clear Layers to clear all layers. Hover the cursor over a marker and click to bring up the name of the daycare, pharmacy, etc.

3.7.3. *Map Features – Map Tab*

The **Map** tab enables different viewing options for the base map. For example, the default setting is **Topo**, or topographical, a mapping style that describes the surface shapes and features. Other choices include **Street**, **Satellite**, **Hybrid**, **Gray**, **Oceans**, **National Geographic**, and **OSM** (©OpenStreetMap contributers). Click Update to submit changes to base map; click Reset to return to default settings.

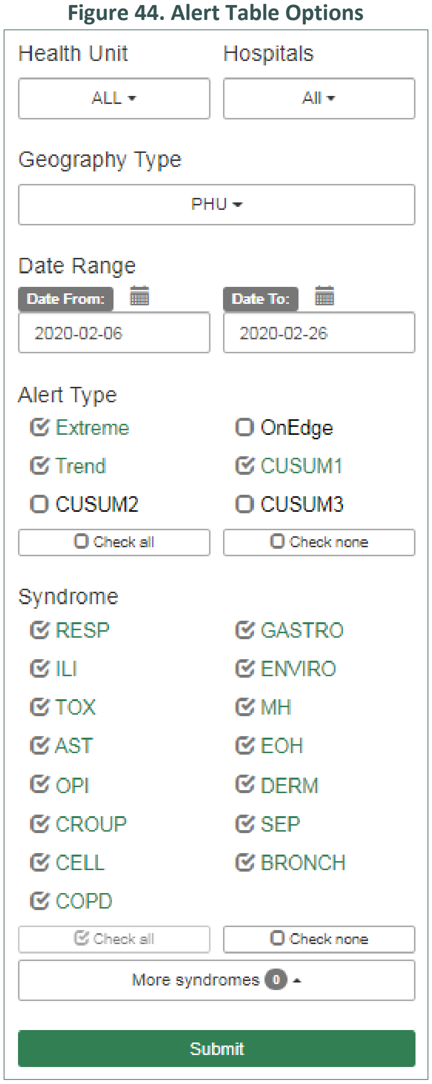
3.8. Alerts

The key benefit of monitoring health outcomes using ACES is its real-time surveillance capabilities; ACES employs mathematical models to identify potentially aberrant patterns in ED visit counts (or admissions counts). These alerts may detect abnormal hospital usage patterns—in real-time—that indicate disease outbreak or other public health concern. Earlier identification can lead to early response, and potentially save lives. Alternately, an alert may identify problems with the collection, transmission, or storage of data received by ACES.

Click the **Alerts** tab on ACES' navigation menu (Figure 20). A table listing all the alerts recorded for the previous 7 days is shown (the data that is shown depends on the user agreement). Information included in this table includes **Alert Date/Time**, **Alert End Date/Time**, **Alert Class**, **Alert Type**, **Syndrome, Geog** (geography) **Type**, and **Geog Name**. Click on the green arrow at the top right corner of the table prompts a dropdown menu enabling *groupby* options described previously (see **3. 2. Line Listings — ED and ED** and Figure 29). Click CSV Export at the bottom left of the table to download a comma-separated values file that can be opened with a spreadsheet program, such as Microsoft Excel or Google Sheets.

To further constrain the data display, a menu of options is at the right of the screen (Figure 44). These include **Health Unit** and **Hospitals** (options available depend on user agreement), **Date Range, Alert Type** (see **Section 2. Alerts and Outbreaks** for description of different alert types), and **Syndrome** (common syndromes are available in the menu, but other syndromes can be selected by clicking **More Syndromes** option). The default alerts displayed are **Extreme**, **Trend**, and **CUSUM1** that generally represent changes in visit counts that are of epidemiological significance. The more sensitive alerts, **OnEdge**, **CUSUM2**,and **CUSUM3** may increase the occurrence of false positive alerts. Presently, the alert algorithms are run on ED visits only.

Figure 44. Alert Table Options



Source: KM 2020

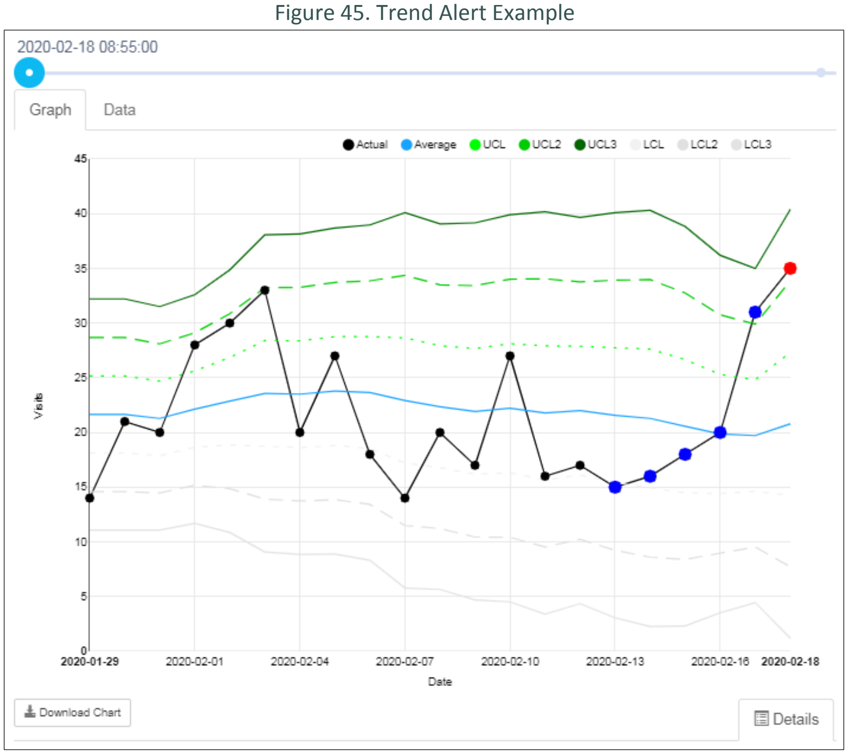
While ACES has over 80 syndromes, alert algorithms are run on only a subset that are identified as high risk for public health impact. The options for syndromes, therefore, are as follows:

- AST (asthma)
- BITE (human, animal, insect—not tick related)
- BRONCH (bronchiolitis, RSV
- CELL (cellulitis, non-wound infection, non-abscess)
- CO (carbon monoxide exposure, exposure to other gases)
- COPD (chronic obstructive pulmonary disease)
- CROUP (croup, PIV)
- DEHY (dehydration)
- DERM (rash, undifferentiated, lesion, wart)
- ENVIRO (heat stroke/syncope/exhaustion, frostbite, hypothermia)
- EOH (alcohol and complications, intoxication, addiction, withdrawal, organ damage)
- GASTRO (gastroenteritis)
- HEP (hepatitis, undifferentiated, A,B,C)
- ILI (fever, myalgia, undifferentiated flu)
- INF (non-specific infections, epiglotitis, tonsil abscess)
- MEN (meningitis, encephalitis)
- MH (mental health)
- MHS (suicidal ideation, attempt or overdose)
- NEC (necrotizing fasciitis, severe cellulitis, gangrene)
- OPI (opioid intoxication, addiction overdose, withdrawal)
- PN (pneumonia)
- REPORT (reportable diseases)
- RESP (respiratory infection non-croup, non-bronchiolitis)
- SEP (bacteremia, sepsis)
- SI (smoke inhalation, chemical, gases)
- TICKS (tick bites)
- TOX (toxicology—not alcohol or opioids, withdrawal, substance abuse, chemical exposure)
- TRMVC (trauma from a motor vehicle collision/accident)
- VOM (vomiting, noro-like illness—not secondary to chemo or with other symptoms)

For more information regarding a specific alert, click anywhere on its line listing in the table and a graph of the data triggering the alert will be displayed in a new window. Depending on the type of alert chosen, various statistical information will be displayed on the graph. For example, Figure 43 shows the data that triggered a **Trend** alert; briefly, a **Trend** alert is triggered by the sixth day in a row with increasing ED visit counts. The legend at the top describes the various information shown in the graph: black circles and line for the data points, the average (in this case, a 14-day moving average), green dotted lines showing the upper control limits (UCL, representing the 1 standard deviation (SD), UCL2 is 2 SD, and UCL3 is 3 SD), and gray dotted lines indicating lower control limits (LCL, LCL2, and LCL3, representing 1 SD, 2 SD and 3 SD, respectively). Click on the symbols in the legend to turn displays on or off. The last 6 data points that caused the alert are shown in blue and red (on the day the alert is triggered). Although there are no points greater than the UCL3, an alert is triggered because the rule has been satisfied for a **Trend** alert (i.e., 6 increasing data points in a row). Note that although statistical information is included in the graph, a **Trend** alert is based solely on the last six data points.

Choose the **Data** tab at the top right of the graph to show the same data in tabular format. Click on the **Details** tab at the bottom right to view the details of the data displayed. Click **Download Chart** to download a png-formatted image of the graph.

Figure 45. Trend Alert Example



Source: KM 2020

3.8.1. *Alerting Protocols*

For a detailed description of all the alerts used with ACES, see **Section 2. Alerts and Outbreaks**.

Three protocols are included in the following outlining steps recommended in response to an ACES alert—the protocols can be reproduced and printed for easy access during an investigation, or used as a framework for the development of local response protocols:

1. **ACES: Investigating Alerts**. A general checklist of investigation steps.
2. **Respiratory or Gastrointestinal Outbreaks**. This checklist is specifically developed to for the investigation of respiratory or gastrointestinal outbreaks
3. **Risk Assessment of ACES Alarms**. This tool was developed for for use during the 2015 Pan Am/Parapan Am Games in Toronto. This tool helps investigators give an alert a numerical ranking to help guide a potential response.

ACES: INVESTIGATING ALERTS

Suggested Actions to Assess an Alert

1. Confirm the Syndrome Classification

- ☐ Use the **Line Listings – ED** tab to view the individual ED visits causing the alert—click on the patient line listing and the full record appears as a separate window.
- ☐ Check that the syndrome classification matches the chief complaint.
- ☐ Check the other potential syndrome classifications on the **Details** tab, **Most Likely Syndromes**. If the syndrome classification is incorrect or inconsistent, make note of any discrepancies and contact ACES at kflaphi@kflaph.ca.
- ☐ See **Section 3.4.3 Viewing an Individual Line Listing** .

2. Create an Epicurve of the Syndrome/Cases

- ☐ Use the **Epicurves – ED** tab to examine the data trend causing the alert by creating an epicurve.
- ☐ Customize the data displayed using the **Tools** and **Advanced** options menu.
- ☐ Display statistics and/or normalize the data to enhance the graph using the options available in the legend.
- ☐ See **Section 3.3. Epicurves – ED and AD**.
- ☐ Use the **Alerts** tab to examine the cases specific to an alert: click on the alert to see all relevant cases.
- ☐ See **Section 3.7 Alerts**.

3. Map the Syndrome

- ☐ Use the **Maps** tab to investigate the geographic dispersion of the cases. Use different geography levels (FSA, county, PHU) to see if a syndrome is specific to a small or large area.
- ☐ If clustering is evident, investigate cases at schools, daycares, long-term care facilities, and other sources of data to guide next steps.
- ☐ See Section **3.6 Maps**.

4. Determine Populations at Risk

- ☐ Determine the population(s) at risk (e.g., children, older adults, individuals residing in an area defined by a postal code or FSA) using steps 2 and 3.

5. Contact Healthcare Professionals

- ☐ If an outbreak is suspected, notify the hospital(s), physicians, local PHU offices and (potentially) other PHUs depending on the scope and if further investigation is required.

NOTE: PHUs can raise awareness amongst the relevant hospital(s) regarding the syndrome to enable more efficient diagnosis and to implement necessary and appropriate precautions, such as infection control procedures. The hospital(s) may also provide additional information to aid the investigation, such as identifying additional cases.

- ☐ Contact the Hospital Infection Control Practitioner (ICP) or designate Infection Control staff member at the local hospital or directly contact the call Nurse on the floor for information regarding admitted patients, according to hospital protocol.
- ☐ Ensure all relevant case information is collated in preparation for the call (date/time of visit, hospital, number of cases, comparison to seasonal trends, lab data if available, etc.).

NOTE: Lines of communication between PHU and the healthcare system is an important part of this process. A predefined internal process for communication between PHU, hospitals and other stakeholders is suggested to improve investigation and follow-up.

6. Contact Hospital/Public Health Laboratory

- ☐ If appropriate, contact the hospital's laboratory (for acute care visits or admitted patients), Public Health Laboratory (for samples related to outbreak investigation and tests outlined on the *Ontario Public Health Laboratory Test Directory*), and/or private laboratories to request number of test requisitions, positive results (preliminary or otherwise), negative results, type/species identification, etc., that may be associated with the syndrome under investigation.

7. Monitor Real-Time Cases using ACES

- ☐ Continue to monitor ACES for real-time ED visits and/or admissions of the syndrome of interest, particularly the spread of disease, geospatial analysis, changes in patient demographics and disease severity (CTAS levels). Contact hospital(s) as required.

KFL&A Public Health

RESPIRATORY OR GASTROINTESTINAL OUTBREAKS

Suggested Actions to Monitor an Outbreak Using ACES

Notification of Outbreak

Public Health staff are notified by a laboratory, an institution such as long-term care facility or daycare, physician or other healthcare professional of an infectious disease event requiring further investigation.

In most cases, this notification concerns a reportable disease. Public Health investigation is warranted for most reportable diseases, unusually high incidence of disease (particularly in institutions), new or emerging diseases, or any other infectious disease event deemed to be a threat to the health of the public. Notification may come to any of the appropriate infectious disease team members during regular business hours or to the Medical Officer of Health or assigned back-up during evenings and weekends.

ACES Investigation

Access ACES to examine the syndrome of interest during the time of exposure and outbreak, as well as demographics and the location of the outbreak as described in the protocol document **ACES: Investigating Alerts** or using the following steps:

1. Alerts Tab: Check the **Alerts** tab in the ACES application.

- ☐ Is there an alert regarding a related syndrome? Check the more sensitive alerts (OnEdge, CUSUM2, CUSUM3)—is an alert generated?
- ☐ Change the Date Range to a longer (or shorter) period representing the time of the outbreak.
- ☐ If an alert for the syndrome is in the table, click to display the cases that are associated with that alert. Follow the steps outlined in the **ACES: Investigating Alerts** protocol.
- ☐ If no alert is in the table, specific cases can still be identified and investigated—continue to the following steps.

See **Section 3.7 Alerts**.

2. Line Listings – ED Tab: Check the **Line Listings - ED** tab in the ACES application.

- ☐ Sort the line listings table by syndrome (click on the column heading labeled Syndrome, or use the *groupby* function) and identify cases with related syndromes. Click on the line listing to display the details of the visit. Do the chief complaints match the syndrome? Are there patterns of age, sex or geography evident? Document the number of cases, demographics, or other relevant information for the investigation.

See **3.4. Line Listings – ED and AD**.

3. Epicurve – ED Tab: **Create an epicurve of the syndrome/cases.**

- ☐ Use the **Epicurves – ED** tab to examine the data trend causing the alert by creating an epicurve. Customize the data displayed using the **Tools** and **Advanced** options menu.
- ☐ Display statistics and/or normalize the data to enhance the graph using the options available in the legend.

See **Section 3.3. Epicurves – ED and AD**.

4. Maps Tab: Use the **Maps** tab to investigate the geographic dispersion of the cases.

- ☐ Customize the map for related syndromes and time range. Use different geography levels (FSA, county, PHU) to see if a syndrome is specific to a small or large area.
- ☐ If clustering is evident, investigate cases at schools, daycares, long-term care facilities, and other sources of data to guide next steps.

See Section **3.6 Maps**.

5. Identify Populations at Risk

- ☐ Identify and document the population(s) at risk (children, older adults, geographical area) using steps 1 through 4.

6. Contact Healthcare Professionals

- ☐ Contact the relevant healthcare facility(ies) for additional cases and observation to corroborate ACES findings and extend investigation.
- ☐ Notify the hospital(s), physician(s), PHU branch offices and potentially other PHUs depending on the scope of the outbreak and if further investigation is required. Work with PHU staff to raise awareness and implement public health action, as necessary.

7. Monitor Real-Time Cases using ACES

- ☐ Continue to monitor ACES for real-time ED visits and/or admissions of the syndrome of interest, particularly the spread of disease, geospatial analysis, changes in patient demographics and disease severity (CTAS levels). Contact hospital(s) as required.

KFL&A Public Health

ACES ALERTS: RISK ASSESSMENT

Alert and Document Actions Based on Risk Assessment

RISK ASSESSMENT CHECKLIST

		SCORE		TOTAL
SYNDROME	1. Is there appropriate classification of the syndrome?	Yes = **1** No = **0**		
	2. Is it a syndrome of public health concern? *Note: take into consideration, for example, seasonality and event planning.*	Yes = **1** No = **0**		
	3. Would it require urgent investigation or follow up by public health?	Yes = **2** No = **0**		
	4. Does it inform situational awareness?	Yes = **1** No = **0**		**/5**
EXCESS COUNTS	1. Check ACES normalized function of syndrome in question (% of total visits). Is the number of syndrome specific visits accounting for a disproportionate amount of total visits to a given geography?	Yes = **1** No = **0**		
	2. Is the excess dispersed across entire public health unit geography (large geography) or confined to a smaller area? (e.g., CSD, event site)	Small geography = **2** Large geography = **1**		
	3. Which alerts were set off?	SPC Extreme, CUSUM = **2** All others = **1**		**/5**
SEVERITY	1. Review CTAS codes, age distribution, and admission to hospital pattern for syndrome. *NOTE: If CTAS codes equal 1 or 2 and admissions for similar symptoms are apparent and increasing = 1, otherwise = 0.*	CTAS 1, 2 = **1** CTAS ≠ 1,2 = **0**		
	2. What is the timing in relation to an event (is there a risk or association)?	<24 hours post event = **2** 24-48 hours post event = **1** 48+ hours post event = **0**		
	3. Is there potential for public concern?	Yes = **1** No = **0**		
	4. Is there potential for media attention?	Yes = **1** No = **0**		**/5**
GEOGRAPHY	Is there evidence of a point source?	Yes = **1** No = **0**		
	Is there evidence of multiple geographic areas being affected?	Yes = **1** No = **0**		
	Is there potential for water distribution system involvement? Is there potential for a vector borne or airborne disease?	Yes = **1** No = **0**		
	Does it involve visitors (postal code assessment)?	Yes = **1** No = **0**		**/5**
MULTI-SYSTEM ALARMS	1. Is there lab confirmation? If Yes, consider requesting additional lab sampling or data from health system partners (e.g., cultures, PCR).	Yes = **2** No = **0**		
	2. Does alert coincide with environmental data (e.g., AQHI)?	Yes = **1** No = **0**		
	3. Is there correlation with other data or intelligence sources? For example, Telehealth, WHO, CDC, Healthmap.org, PHAC, CNPHI, Epi-x, Pubmed, GOARN? Or vector data, such as: mosquito trap, WNV, EEV, percentage positivity of Ixodes ticks)?	Yes, multiple correlations = **2** Yes, single correlation = **1** Maybe = **1** No = **0**		**/5**
ALARM FREQUENCY	1. Are multiple different alert algorithms setting off for same syndrome and geography?	Yes = **1** No = **0**		
	2. Are alerts continuing for hours or days? Short duration alerts could indicate false alarms.	Yes = **1** No = **0**		**/2**
SEASONAL EXPECTATIONS	1. Is the increase in counts unusual for the time of year (syndrome dependent)? Check normalized graphs for abnormalities in relation to main syndromes of interest. Respiratory + ILI typically follow low levels in summer months. Keep heat/cold alerts and weather patterns in mind).	Yes = **3** Maybe = **2** No = **0**		**/3**
	If score <16, document and review next day. If score is between 16 - 22, discuss with a member of the KFL&A Public Health Informatics Team. If score > 22, further investigation necessary and quick action likely required.		TOTAL SCORE	**/30**

Appendix A: References

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Appendix B: ACES Syndromes

*Bold indicates syndrome is monitored in using anomoly identification algortihms for real-time alerts (asee **2.3 Alerts and Outbreaks**).

ACES Code	Syndrome Description
ALLERG	allergic reaction, angioedema (not bee sting)
AST	asthma, wheeze, difficulty breathing, SOB
BITE	human, animal, bug (not tick-related)
BRONCH	bronchiolitis, RSV
BURN	burns: chemical and thermal, electrical shock
CAD	coronary artery disease, chest pain
CARD	pericarditis, effusion, myocarditis, endocarditis
CDIFF	C. difficile
CELL	cellulitis, non-wound infection, non-abscess
CHF	congestive heart failure
CO	carbon monoxide exposure or other gases (e.g., sulphur)
CONC	concussion, head injury
COPD	chronic obstructive pulmonary disease
CROUP	Croup (parainfluenza viruses)
CV	cardiovascular (excludes MI and strokes; includes peripheral vascular disease)
DEHY	dehydration
DENT	dental pain, infection, tooth trauma, etc.
DERM	rash, undifferentiated, lesion, wart
DM	diabetes, related complications
ELECT	electrolyte imbalance, hyperkalemia, hypomagnesium, hyponatremia
ENT	related to ears nose throat-surgery, tinnitus
ENVIRO	heat stroke, heat syncope, heat exhaustion, cold-frost bite, hypothermia
EOH	alcohol related: intoxication, addiction, withdrawal, end organ damage
FALL	undifferentiated falls
FBI	foreign body ingestion
FEB	febrile neutropenia
GASTRO	gastroenteritis
GB	Guillain Barre syndrome, flaccid paralysis
GI	GI bleed (upper and lower), epistaxis, hemoptysis
GMED	general medical admission, (e.g., unconscious, weakness, unwell, chronic diseases)
GNSURG	general surgical admission-appendicitis, cholecystitis, bowel obstruction
GYN	gynecological, bleed, hysterectomy, PID
HEAD	non-traumatic undifferentiated headache,
HEM	hematological condition, anemia, thrombocytopenia (not oncological)
HEP	Hepatitis; undifferentiated, A,B, and C
ILI	fever, myalgia, undifferentiated flu
INF	non-specific infections: potential interest to public health, epiglottitis, tonsil abscess
INJ	sprain, strain, laceration, dislocation, bruise, swelling
INS	insomnia, sleep disorder

ACES Code	Syndrome Description
INT	intussusception
LAC	lacerations
MEDREN	medication renewal
MEDSE	medication side effect
MEN	meningitis and encephalitis
MH	mental health
MHS	suicidal ideation (attempt or overdose)
MIGR	Migraine
NEC	necrotizing fasciitis, severe cellulitis, gangrene
NEURO	dementia, Alzheimer's, stroke, seizure, vertigo, syncope, fainting
NEUS	neurosurgery (e.g., aneurysm, bleed), subdural, SAH
NEWB	newborn
OBS	related to obstetrics
ONC	oncology
OPI	opioid intoxication, addiction, overdose, and withdrawal
OPTH	general ophthalmological condition
ORTHF	non-hip fracture
ORTHH	fracture of the femur or hip
ORTHO	orthopedic elective surgery, cast change or assessment
OTHER	null, missing, other
PAIN	undifferentiated pain, non-cancer, radiculopathy, back pain, sciatica
PE	pulmonary embolism, DHT, VTE
PHYSC	physician consultation
PN	pneumonia
PO	post-operative infection or complication
REN	renal failure, dialysis, renal disease and complications
REPORT	reportable diseases
RESP	respiratory infection non-croup, non-bronchiolitis
SEP	bacteremia, sepsis
SI	smoke inhalation (or chemical, gases)
SOC	social admission
TEST	test results (e.g., blood or diagnostic imaging, x-ray, biopsy, transfusion, tube change)
THOR	thoracic, pneumothorax
TICKS	ticks
TOX	toxicology: withdrawal, substance abuse, chemical exposure (not alcohol or opioids)
TRMVC	trauma from MVC/ATV
TRO	trauma from another means (e.g., fall)
TRW	gunshot or stab, violence, assault
TRS	sexual assault, rape
URO	urological -stones, prostate, UTI
VOM	vomiting-alone-NORO like illness, not secondary to chemo or with other symptoms

APPENDIX C: ICD-10 Codes for Validation of Syndromes

ACES Code	ICD-10 Codes used for Validation with Intellihealth (ED) or DAD (AD) Patient Records
AST	J45, J46, R062, R060
BRONCH	J20, J21, J40, J41, J42, J47
CELL	L03
CO	T58
COPD	J44
CROUP	J05, R061
DEHY	E86
DERM	R21, R22, L01, L08, L20, L21, L22, L23, L24, L25, L26, L27, L29, L30, L40
ENVIRO	T67, T68, T33, T34, T35, L55
EOH	F10, T510
GASTRO	A02, A03, A04, A05, A06, A07, A08, A09
HEP	B15, B16, B176, B18, B19
ILI	R50, J10, J11
MEN	G00, G01, G02, G03, G04, G05, A85, A86, A87
MH	F00, F01, F02, F03, F05, F06, F07, F08, F09, F20, F21, F22, F23, F24, F25, F28, F29, F30, F31, F32, F33, F34, F38, F39, F40, F41, F42, F43, F44, F45, F48, F50, F60, F61, F69, F70, F71, F72, F73, F78, F79, F90, F91, F92, F93, F94, F99
MHS	R458
NEC	M726
OPI	T400, T401, T402, T403, T404, T406, F11
PN	J12, J15, J16, J17, J18
RESP	J00, R05, J01, J02, J03, J04, J05, J06, J22, J31, J32, J37, J39
SEP	A40, A41
SI	J68, T59, J708, J709
TOX	F12, F13, F14, F15, F16, F19, T39, T405, T407, T408, T409, T42, T43, T46, T48
VOM	R11