## Introduction:

The last 2 decades have seen a substantial increase in the development of clinical prediction rules (CPRs) to assist health care professionals in risk stratification, outcome prediction and management strategy determination.[1–4] CPRs provide an objective measure to guide management.[5–7] In addition, the use of departmental clinical pathways, protocols and guidelines, also known as Evidence Based Clinical Algorithms (EBCAs), has increased in the Emergency Department (ED) setting.[8–10] Providing standardized care based on best evidence, EBCAs have been shown to improve outcomes and standard process metrics within the ED.[11–13]

The majority of CPRs are derived and validated for physician use. However, newer strategies include the integration of CPRs into EBCAs for multi-disciplinary environments, like the ED.[14–17] Incorporating previously validated CPRs into nursing practice has developed a new generation of EBCAs: Advanced Nursing Directives (ANDs).[18,19] ANDs serve as screening tools empowering nurses to provide advanced levels of care prior to physician assessment. Implementation of ANDs in the ED have shown significant improvement in patient satisfaction and efficiency.[20–22]

Appendicitis is the most common non-traumatic emergency in children.[23] In an effort to improve patient care and key department flow metrics for children presenting with right lower quadrant pain (RLQ), our Pediatric ED implemented an AND as well as a comprehensive care map (Appendix 1, 2). Using criteria modified from the Alvarado score[24] our appendicitis AND aims to improve early identification of children at high risk of appendicitis and reduce the time to key investigations while limiting the number of unnecessary painful procedures. The objectives of this study were to determine whether children who met criteria for an AND for right lower quadrant pain had better department flow metrics compared to those who did not meet criteria, and to determine whether a positive AND screen could identify children who required any further investigation/intervention to diagnose and manage appendicitis.

## Methods

Study Design: A post-implementation cohort study.

Study Setting: The Alberta Children's Hospital (ACH) Pediatric ED is the tertiary referral centre for Southern Alberta, Western Saskatchewan and Eastern British Columbia, a catchment area of 1.8 million. Care is provided for approximately 70 000 visits yearly.

Study Population: Children aged 3 to 17 years presenting to the ED with abdominal pain who were evaluated by ED staff nurses using the departmental AND for RLQ pain were eligible for study. Those children with abdominal pain in whom the AND form was not completed and those with previous appendectomy were excluded.

The Care Map and Advanced Nursing Directive:

The Alberta Children's Hospital Appendicitis Committee included representation from Emergency Medicine, Emergency Nursing, Surgery, Radiology, Infectious Disease, Anesthesia, and Pharmacy Services. Based on a critical assessment of the literature and expert opinion, a comprehensive ED management plan including our AND and care map (Appendix 1, 2) was developed. Approved by the department site-operations committee was obtained.

Assessment components of the AND were modified from the historical and physical exam elements of the Alvarado Score.[24] Modifications included an increase in reported or measured temperature to 38.0C and removal of weighted scoring for individual criteria. The laboratory elements of the Alvarado Score were not included as AND assessment occurs at triage or initial bed-side assessment (i.e. prior to obtaining laboratory investigations). Intervention components of the AND include initiation of intravascular access, obtaining blood and urine for investigation, and initiating a normal saline bolus.

Implementation strategies included a series training sessions for physicians and nurses to ensure familiarity with pathway processes, including formal "lunch-and-learn" sessions, division meetings and rounds. Following a 3-month adaptation period, a pathway evaluation process 6 months in duration was initiated. Health records for all children presenting to the ED with abdominal pain were reviewed to identify those that had been assessed by the nursing staff using the AND. In order to reduce the incidence of missed cases, health records of children who underwent appendectomy during the evaluation period were reviewed to identify those that had been assessed using the AND.

Data abstraction:

Health Records from the ED are a hybrid of hard copy and electronic sources. Data elements that were abstracted from ED charts were entered into a custom electronic database, which was subsequently merged with available electronic health records. Demographics, AND criteria, vital signs, investigations, interventions, ED diagnosis, ED disposition, hospital interventions, pathology

results, hospital diagnosis and hospital disposition were extracted by trained research assistants under the direct supervision of senior staff from the Data Integration Measurement and Reporting (DIMR) of the Alberta Health Services (AHS).

Outcomes:

The main outcomes of interest included the time interval from triage to blood draw and the requirement of any further investigation/intervention to diagnose and manage appendicitis. Time from triage to blood draw was chosen as a process measure because the results of blood tests, particularly the WBC and neutrophil count, are key elements in the Alvarado score and Pediatric Appendicitis Score; optimizing time to lab results has the potential to improve time to disposition planning. Further investigation/intervention was chosen as a measure of accuracy in identifying the appropriate population, and was defined as completion of any of the following: advanced imaging studies (ultrasound – US; computed tomography – CT), surgical consultation, or admission to hospital.

Secondary outcomes included further time intervals (triage to US, admission, appendectomy) as well as key outcome measures in appendicitis: the perforation rate (PR) and the negative appendectomy rate (NAR). Perforation was defined as a pathology report with any mention of perforation or abscess formation. Negative appendectomy was defined as a pathology report indicating no significant pathological abnormality, no inflammation or no evidence of acute appendicitis.

Analysis:

Demographic data was evaluated using descriptive statistics with t-tests for continuous data and chi-squares for categorical data. Odds ratios with 95% confidence intervals were used to describe the difference in investigations and interventions performed. Wilcoxon rank sum defined differences between median times for departmental flow metrics. Overall test characteristics for the AND in identifying children requiring further evaluation were calculated including sensitivity, specificity, positive- and negative- predictive values, and accuracy. Data was analyzed using STATA 12.1 (StataCorp, College Station, TX)

In circumstances where flow metric analysis indicated an event occurred prior to the index triage date and time (i.e. blood test performed in external physician office, urgent care), these values were excluded from analysis.

Ethics:

Protocol review from members of the University of Calgary Conjoint Health Research Ethics Board (CHREB) provided approval of this study as a quality assessment and improvement initiative.

**Results:**

A total of 518 health records were reviewed. An AND for RLQ pain was initiated in 240 children during the 6-month Quality Improvement assessment period. Thirty forms were present on the health record but were not completed and therefore were excluded. Data from the 210 remaining health records were analyzed (Figure 1). Demographics of the patient population are reported in Table 1.

Children who met AND criteria had blood tests done more often (OR 3.28, 95%CI 1.65-6.56) and were more likely to undergo further investigation to rule out appendicitis (OR 2.62, 95%CI 1.40-4.90) than those who did not meet criteria (Table 2). Overall the number of negative appendectomies within each group was not significantly different (5/137, 3.6% vs 2/73, 2.7%; p=0.73); for those diagnosed with appendicitis the NAR was 8.6% for children meeting criteria and 9.1% for those not meeting criteria. Overall the number of perforations was significantly higher in those meeting criteria (17/137, 12.4% vs 1/73, 1.4%; p=0.007); for those diagnosed with appendiciits the PR was 29.3% and 1.6% respectively.

Table 3 outlines the differences in department flow metrics between children who met AND criteria and those who did not, with significant differences in time from triage to blood draw, admission and appendectomy. Table 4 reports the test characteristics of the AND in predicting need for further investigation in the ED.

**Discussion:**

The results of our quality improvement initiative demonstrate that children meeting criteria for our RLQ pain AND have significantly better hospital flow metrics (triage to blood draw, admission and appendectomy) than those not meeting AND criteria. In addition, we have shown that children who met AND criteria underwent further advanced investigations and interventions for suspected appendicitis significantly more often than children who did not meet AND criteria. To our knowledge, this is the first study demonstrating the use of an AND for children presenting to the ED with abdominal pain and its impact on patient care.

The white blood cell count (WBC) and neutrophil count, bio-markers suggestive of infection, are required to calculate frequently used clinical scores including the Alvarado Score[24] and the Pediatric Appendicitis Score[25] and are often one of the earliest steps in the evaluation of a child at risk for appendicitis. In our study population, time to blood sample acquisition in children who met AND criteria was less than half that of those who did not meet criteria, a reduction of 1.5 hours. Assuming that earlier sample acquisition translates to earlier results, implementation of the AND may lead to much earlier calculation of the Alvarado score or PAS, thus optimizing time to clinical decisions regarding the need for further evaluation through imaging and surgical consultation.

The balancing measure for improved flow attributed to the AND is ability of the screening tool to identity which children actually go on to further investigations/interventions. In other words, improving ED flow at the cost of increased unnecessary painful procedures and increased investigation expenses is detrimental to patient care and health systems. The AND should not be seen as a diagnostic tool, but a screen preparing for further investigations. If the tool can identify those going on to imaging or admission for appendectomy, while limiting unnecessary procedures, it is successful. Our results have shown that in children meeting AND criteria the odds of undergoing further investigation/intervention during hospital stay were more than twice that of those not meeting criteria. These results demonstrate that the AND is useful in identifying children who will go on to have further studies, particularly in light of the better department flow metrics. It is possible that the simple fact of having blood tests and intravenous fluids already initiated could bias the managing physicians toward more aggressively investigating for an underlying cause of the abdominal pain. However, we are of the opinion that it is equally as likely that the blood tests results were reassuring, or the fluid administration has improved the patient's pain, thus resulting in fewer investigations; in other words, the clinical outcomes of the AND, being expedited laboratory results and fluid administration, may result in quicker disposition/discharge by physicians. Our results indicate a sensitivity in identifying those children with RLQ pain that go on to further investigation that is comparable to reported sensitivities for the Alvarado score in identifying pathology proven appendicitis (70-85%).[26,27] As the AND is a screening tool and not a diagnostic tool, we feel these are good results. The remainder of the test characteristics were less promising compared to the Alvarado score. These results may be attributed to the

removal of the weighted score that is found in the original Alvarado score, or to the lack of laboratory investigation results, which are also key elements to the Alvarado score.[24] In addition, it is possible that a significant number of nurses may not have completed a AND form for those children with RLQ pain that they felt clearly did not have appendicitis, leading to a low number of children not meeting criteria (and likely low Alvarado Scores), not going on to further investigation, thus influencing the specificity and the negative predictive values. Importantly, the AND is only a portion of the overall department pathway which is used to identify children at risk of requiring further investigations and expedite their care; the diagnostic accuracy of the pathway as a whole including the use of imaging and surgical consultation, should be further evaluated.

Our secondary objectives included an assessment of other hospital time metrics, including time to imaging, admission and appendectomy. In order to minimize radiation exposure,[28] the imaging modality of choice at our hospital is US. Our results did not demonstrate a statistical difference in time to US based on AND criteria. The most likely explanation for the lack of statistical significance relates to the fact that appendectomy is rarely performed at our centre during the night (as a result of the increasing evidence that delaying appendectomy until day-time hours is safe practice)[29,30] and therefore children presenting with RLQ pain to our ED during night-time hours are held in the ED until their imaging studies are performed in the morning. Time to admission and time to appendectomy has the potential to significantly impact overall ED patient flow by the resultant increase in open ED bed space. Many factors must be considered when examining time to admission and surgery: time to investigation results, time of consults, inpatient bad capacity, surgical suite and surgeon availability. Our results demonstrate that time to admission and time to appendectomy are significantly lower in children who were met AND criteria.

The results of our study confirm those from previous studies demonstrating that implementation of ANDs in the ED have a significant impact on ED flow metrics. These studies have focused on improving time to analgesia administration,[31,32] obtaining basic imaging studies[14,16,33–35] or administration of corticosteroids in pediatric asthma.[22,36] For these ED presentations, previously validated criteria were used to identify patients who would most benefit from early nurse intervention. Examples include the Faces Pain Scale, the Ottawa Ankle Rules[12] and the Pediatric Respiratory Assessment Measure.[37] In our AND, we make use of elements of the well-studied Alvarado Score.[24] Using previously validated scores allows for distinct criteria for patient selection in order to decrease potential ambiguity for initiation of the nursing interventions.

In our study, the NAR was no different between groups. The purpose of the AND is not to diagnose appendicitis, but rather to expedite the process of arriving to a management plan. The ultimate decision to perform appendectomy is surgeon-dependent, and relies on information received after initial evaluation in the ED, including imaging studies, repeat examinations etc, and is not dependent on whether the AND is performed. Thus, we would not expect that the NAR would be

different between groups. However, PR was higher in those children meeting AND criteria. It is possible that those with perforation were more like to exhibit features consistent with the AND criteria, thus leading to higher proportion of positive AND screen in this population.

Future quality improvement initiatives should look at optimizing the test characteristics through weighting of the score criteria as well as determining health care provider and parent thresholds for the number needed to treat related to time savings and unnecessary procedures.

## Limitations

Our analysis is limited by its reliance on health record documentation, including missing data and the requirement for linkage of both paper and electronic resources. However, several data points were available in both formats and compared to ensure accuracy. In addition, it was not possible to assess whether outcomes of the AND (blood and urine results, pain improvement post bolus etc.) provided reassurance or an alternate diagnosis to the treating physician. In these cases, no further evaluation would have been performed, but a sense of the utility of the AND would not be available. This is an area for future assessment.

**Conclusions:**

Children presenting to the ED with RLQ pain who meet the criteria for an Advanced Nursing Directive are more likely to require ongoing investigation and intervention to rule out appendicitis than those who do not meet criteria. In addition, those meeting AND criteria have better department flow metrics including shorter time to blood sample acquisition, admission and appendectomy. The results of this quality improvement initiative indicate a strong future for the role of ANDs in the ED. Future quality initiatives should focus on optimizing test characteristics of the AND as well as assessing both health care provider and parent perceptions regarding ANDs in the ED.

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