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Electronic-prescribing tools improve N-acetylcysteine prescription accuracy and timeliness for patients who present following a paracetamol overdose: A digital innovation quality-improvement project

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Abstract

Objectives: Prescription error rates and delays in treatment provision are high for N-acetylcysteine (NAC) when prescribed for paracetamol overdose (POD). We hypothesised that an electronic tool which proposed the complete NAC regimen would reduce prescription errors and improve the timeliness of NAC provision. Error rates and delays in the provision of NAC were assessed following POD, before and after the implementation of an electronic prescribing tool.

Methods: The NAC electronic prescribing tool proposed the three NAC infusions (dosed for weight) following entry of the patient's weight. All NAC prescriptions were reviewed during a three-month period prior to and after the tool's implementation. Error rates were divided into dose, infusion volume or infusion rate. Delays in NAC provision were identified using national Emergency Medicine guidelines.

Results: 108 NAC prescriptions were analysed for all adult patients admitted to the emergency department of a secondary care hospital in the UK between July–September 2017 and August–October 2018, respectively. There were no differences in the demographics of patients or the seniority of the prescribing clinician before or after the introduction of the electronic tool. The electronic prescribing tool was associated with a decrease in prescribing errors (25% to 0%, $p < 0.0071$) and an increase in the provision of NAC within recommended times (11.1% to 47.4%, $p = 0.029$).

Conclusions: An electronic prescribing tool improved prescription errors and the timeliness of NAC provision following POD. Further studies will determine the effect of this on length of stay and the benefit of wider implementation in other secondary care hospitals.

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Introduction

Paracetamol overdoses (POD) account for 48% of all cases of poisoning presenting to hospital in the UK and are associated with an estimated 100 to 200 deaths per year.[1] N-acetylcysteine (NAC) is the mainstay of treatment for POD. Timely and accurate prescriptions for this antidote have been shown to reduce mortality from 5% to 0.7%.[2]

The dosing regimen for NAC is complex. It consists of three different doses, each of which must be calculated using the patient's weight and then administered in a different volume that runs at a different infusion rate. As a result of this complexity, prescription errors and delays to administration occur, leading to a reduction in treatment efficacy and a risk of adverse events caused by either under or over exposure to the antidote.[3] In one study, errors were found in 50.6% of NAC prescriptions in terms of fluid type or volume, in 13.6% of NAC doses and in 11.1% of infusion rates.[4] Other studies have quoted even higher error rates in NAC prescriptions,[5] suggesting this is a widespread challenge. As well as errors in prescribing there are often delays in initiating the NAC infusion, with one study noting that 68% of NAC infusions failed to meet treatment targets.[6]

Electronic prescribing (EP) systems have been shown to improve inpatient medication management and so offer a potential solution.[7,8] Birmingham Systems Prescribing Information and Communications System (PICS) is a rules-based prescription-support system that provides real-time drug prescribing checks and recommendations.

Following a multidisciplinary consultation between clinicians, pharmacists and the PICS programming team, a PICS EP tool was designed to automate the prescription for the complete dosing regimen of NAC. This was implemented in July 2018 at the Queen Elizabeth Hospital Birmingham (QEHB), part of University Hospitals Birmingham NHS Foundation Trust.

This quality improvement project aimed to assess the digital tool's impact on the accuracy and timeliness of NAC prescriptions for POD.

Methods

The PICS EP tool proposed prescriptions for the complete NAC regimen, using an algorithm which required the clinician to input the patient's weight and then confirm the automatically proposed doses, rates and volumes.

To assess the impact of this tool, the medical records of all patients who were prescribed NAC following a POD were reviewed retrospectively during two three-month periods before and after the tool's introduction: July-September 2017 and August-October 2018, respectively. Notes were reviewed by four independent clinicians blinded as to whether the prescription was performed before or after the adoption of the EP tool. Results were confirmed by the senior author.

Patients were divided into four categories depending on the time from the POD and the patient's attendance at hospital: 0–8 hrs, 8–24 hrs, >24 hrs or staggered. Accuracy was assessed by manually reviewing medication charts for NAC-prescribing errors and deemed to be correct or incorrect based on the dose of NAC prescribed, the fluid volume and the fluid infusion rate. Timeliness was assessed against two of the College of Emergency Medicine standards for POD.[9] For POD presenting at 8–24 hrs, NAC should be prescribed immediately if >150 mg/kg of paracetamol was ingested; in staggered POD, NAC should be started within one hour of arrival.

In this pilot study, all PODs were included. All data were compared using Fisher's exact test and $p < 0.05$ was taken to be statistically significant.

Results

108 cases of POD and the associated NAC prescriptions were analysed during the two data collection periods. All adult patients (aged $\geq$18 years) who were admitted to the emergency department (ED) of QEHB with POD were included in the study unless they had been directly admitted to the intensive care unit, in which case they were excluded.

Prior to the tool's introduction, 51 cases were included, consisting of 14 men and 37 women with a mean age of 39.8 years [SD 21.6–58.0]. Following the tool's introduction, 57 cases were included, consisting of 17 men and 40 women with a mean age of 35.1 years [SD 17.7–52.8]. There were no differences between the demographics of these patient cohorts. There were also no differences in the seniority (by grade) of the prescribing clinician before or after the introduction of the tool. The majority of prescribers were early or middle grade clinicians working in the Emergency Department (ED) or Acute Medical Unit.

Drug prescribing errors were reduced and timeliness was improved following the introduction of the EP tool

Table 1 describes the error rates for the prescriptions. Prior to the tool's introduction, 13 (25.5%) NAC prescriptions contained errors. The causes of these errors were incorrect dose (10, 76.9% of errors), incorrect infusion rate (2, 15.4% of errors) and incorrect fluid volume (1, 7.7% of errors). None of these prescription

Table 1. Comparison of NAC prescription errors and timeliness before and after the introduction of the NAC-electronic prescribing (NAC-EP) tool.

	POD 0–8h		POD 8–24h		POD >24h		Staggered POD	
	Before EP n = 26	After EP n = 30	Before EP n = 5	After EP n = 7	Before EP n = 2	After EP n = 1	Before EP n = 18	After EP n = 19
Prescription Errors	6 (23.1%)	0 (0%) *p = 0.0071	2 (40.0%)	0 (0%)	1 (50%)	0 (0%)$	4 (22.2%)	0 (0%) *p = 0.046
Achieved timeliness standards	–	–	2 (40.0%)	5 (71.4%)	–	–	2 (11.1%)	9 (47.4%) *p = 0.029

n = Total number of NAC prescriptions in each category.
*Fishers Exact test.
$Numbers too small for statistical comparison.

errors were associated with patient harm, defined as an adverse drug reaction or a failure to treatment which had been recorded in the medical notes. Following the tool's introduction, no prescribing errors were noted in any of the four categories.

The timeliness of NAC prescriptions also improved following the tool's introduction. There was a significant improvement in the proportion of staggered POD cases who received NAC within one hour of presentation (p = 0.029, Fisher's exact test). There was also an improvement in the proportion of POD cases who received NAC immediately after ingesting >150 mg/kg of paracetamol and presenting between 8–24 hours. This improvement was not significant which may be related to the small sample size.

In addition to the pre-defined standards for timeliness, other improvements were noted during data collection and analysis. Prior to the tool's introduction, it was noted that 28 (54.9%) NAC prescriptions were missing the prescription of at least one of the three infusions when the patient left ED. This may have led to delays in the prescription and administration of the complete NAC regimen in the Acute Medical Unit. Following the tool's introduction, the complete NAC regimen was prescribed at the same time for every patient while they were still in ED.

Discussion

This study reinforces the benefits of a well-designed EP tool on the quality of patient care. By designing and implementing a tool that proposed prescriptions for the complete NAC regimen based on the patient's weight, a multidisciplinary team at QEHB managed to reduce NAC-related prescription errors from 25.5% to zero. In addition, the tool was shown to improve the

timeliness of prescriptions based on both the ED standards and additional observations made during data collection.

However, while the tool eradicated NAC-prescribing errors, it was unable to rectify all of the identified delays. Over 50% of NAC prescriptions for staggered POD failed to meet the one-hour target after the tool was introduced. While EP tools are an effective means of improving patient care, this finding demonstrates that they should not be used in isolation. Following this quality improvement process, targeted education sessions have been proposed to ensure that all clinicians are aware of the recommendations surrounding NAC in POD.

This study has limitations. While it has demonstrated marked and significant improvements following the implementation of the PICS EP tool, it was conducted in a single site which has sufficient digital maturity to deliver such a tool. Digital maturity varies across hospitals so the utility of this tool should be examined in other acute health care settings. In addition, the study only included a small sample of cases and the data were collected retrospectively. Furthermore, the study did not explore delays to the administration of NAC, only delays to its prescription.

As a result, further work is required to confirm that the findings of this study are generalisable across the NHS. Such work might explore whether a link exists between the studied quality improvement measures and factors such as patient outcome and overall length of stay. The analysis of these data would support other trust in exploring the cost-effectiveness of implementing or extending EP systems throughout their hospitals.

and QS collected the data; AM, ES and ASec analysed the data; AM, ES and ASec drafted the article. All authors reviewed and edited the manuscript and approved the final version.

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