SHORT REPORT

Weight-based N-acetylcysteine dosing chart to minimise the risk of calculation errors in prescribing and preparing N-acetylcysteine infusions for adults presenting with paracetamol overdose in the emergency department

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Management of paracetamol overdose (POD) is common in the emergency department (ED) and forms part of the clinical effectiveness audit programme of the British Association for Emergency Medicine. N-acetylcysteine (NAC) infusion regimens for the treatment of POD are complicated and prescribing and administration errors have been well documented. This study assessed the ability of doctors and nurses to calculate correct doses using manual calculation skills and a weight-based NAC dosing chart when prescribing and preparing NAC infusions. With manual calculations, errors were made by doctors and nurses in 26% of cases collectively. No errors were made using the dosing chart. The dosing chart ensured 100% accuracy in dose calculations, which may translate into improved patient safety.

Treatment of paracetamol overdose (POD) with N-acetylcysteine (NAC) prevents hepatic failure. Suboptimal treatment may adversely affect patient outcome. NAC infusion regimens require complex calculations to be made by both prescribers and nurses preparing infusions.¹ Errors with intravenous medicines requiring multiple step preparation or complex calculations have been highlighted.^{2,3} The use of dosing charts to prevent medication errors associated with complex calculations has been proposed by the Department of Health as a risk reduction strategy.⁴

Typically, doses of NAC, diluent fluids and their volumes and durations of infusions are prescribed by doctors on intravenous infusion charts. In the UK, the preparation and administration of parenteral treatment is usually performed by trained nurses who calculate volumes of a 20% NAC solution (Parvolex®) required to prepare infusions based on doctors' prescriptions. When preparing NAC infusions, calculation errors have resulted in doses varying by more than 50% from the intended dose.⁴

In 2005, there were 112 000 attendances to our emergency department (ED). Approximately 80 patients per month presented with a POD and 25% of these were treated with NAC. The infrequency with which NAC dose and volume calculations are performed in our department may increase the risk of medication errors. Most NAC prescribing for POD is initiated in EDs where pharmacists do not routinely check prescriptions or drug administration to ensure safe medicine use. Incorrect prescriptions for NAC infusions initiated in the ED have been identified and corrected by pharmacists when patients have been reviewed following admission to wards.

The aim of this study was to compare the accuracy of doses and volumes calculated manually by ED staff when prescribing and preparing NAC infusion regimens with those derived from a weight-based NAC dosing chart.

METHODS

A weight-based NAC dosing chart (fig 1), based on the standard treatment regimen for POD in adults (<http://www.spib.axl.co.uk>; <http://emc.medicines.org.uk/emc/industry/default.asp?page=displaydoc.asp&documentid=1127>),⁵ was designed by pharmacists in conjunction with ED practitioners. Doctors and nurses of all grades involved in NAC prescribing and administration in the ED completed two written assessments. In each assessment, individual doctors were required to calculate and prescribe a NAC infusion regimen for a hypothetical patient weighing 58 kg. Each participating nurse was asked to calculate volumes of NAC required to prepare infusions against an accurate prescription for a hypothetical patient weighing 58 kg. Assessment I (manual) was completed according to current practice by the study participants using their mathematical skills and preferred personal method. TOXBASE (<http://www.spib.axl.co.uk>), British National Formulary, calculators and supplies of NAC ampoules, including product information, were available. Assessment II was completed with the aid of the dosing chart (fig 1) which describes doses and volumes of NAC for each of the three regimens for adult patients with weights ranging from 40–110 kg (maximum patient weight for calculation of NAC doses) (<http://www.spib.axl.co.uk>).

RESULTS

Assessments were completed by 27 doctors and 53 nurses (table 1). In assessment I, doctors calculated 81 doses on 27 prescriptions. Five dose errors (5/81, 6%) were made by three doctors (3/27, 11%) on three prescriptions. Prescribing errors included two 1000-fold underdose errors in the 15 min and 4 h regimen, respectively, a 14% underdose in the 4 h regimen, and two overdoses of 50% and 53% in the 16 h regimen.

Nurses performed 159 volume calculations on 53 prescriptions. Thirty-eight volume miscalculations (38/159, 24%) were made by 18 nurses (18/53, 34%) on 18 prescriptions. Volume errors in the 15 min regimen ranged between –80% and +1230% of the prescribed dose. Errors in both the 4 h regimen and the 16 h regimen ranged between –80% and +1059% of the prescribed dose. Twenty-one errors were underdoses (21/159, 13%).

In assessment II, no errors were made by doctors or nurses in determining either doses or volumes.

The quantification of error reduction introduced by use of the NAC dosing chart was carried out using the intra-class correlation coefficient (ICC) and coefficients of variation (CV)

Abbreviations: CV, coefficient of variation; ED, emergency department; ICC, intra-class correlation coefficient; NAC, N-acetylcysteine; POD, paracetamol overdose

Adult N-acetylcysteine prescription (Parvolex® ampoule = 200 mg/ml N-acetylcysteine)					Please circle appropriate weight, dose and volume and sign appropriate prescription row				
Regimen		Dose 1		Dose 2		Dose 3		Further doses should be continued on the IV fluid chart	
Fluid		200 mls 5% glucose		500 mls 5% glucose		1000 mls 5% glucose			
Duration of Infusion		15 minutes		4 hours		16 hours			
Drug dose		150 mg/kg N-acetylcysteine		50 mg/kg N-acetylcysteine		100 mg/kg N-acetylcysteine			
Weight (kg) Round up to next 5kg (circle)		Dose (mg)	Ampoule Vol* (ml)	Dose (mg)	Ampoule Vol* (ml)	Dose (mg)	Ampoule Vol* (ml)	Dr signature	Rx time
40		6000	30	2000	10	4000	20		
45		6750	34	2250	12	4500	23		
50		7500	38	2500	13	5000	25		
55		8250	42	2750	14	5500	28		
60		9000	45	3000	15	6000	30		
65		9750	49	3250	17	6500	33		
70		10 500	53	3500	18	7000	35		
75		11 250	57	3750	19	7500	38		
80		12 000	60	4000	20	8000	40		
85		12 750	64	4250	22	8500	43		
90		13 500	68	4500	23	9000	45		
95		14 250	72	4750	24	9500	48		
100		15 000	75	5000	25	10 000	50		
105		15 750	79	5250	26	10 500	53		
≥ 110	Max dose	16 500	83	5500	28	11 000	55		
Admin record		Time given	Given by	Time given	Given by	Time given	Given by		

Figure 1 Weight-based N-acetylcysteine (NAC) dosing chart for adults.

#This prescription chart is a modified version of the dosing chart used in assessment II. The original chart described doses and volumes for all weights between 40–110 kg. For use in clinical practice, weight increments of 5 kg only have been included.

*The calculated Parvolex (200 mg/ml NAC) volumes are compatible with the dosing calculator provided by TOXBASE (<http://www.spib.axl.co.uk>) which aids calculation of NAC dose in millilitres from the patient's weight. All volumes are rounded to the nearest millilitre for ease of measurement.

for doctors and nurses in each part of the NAC regimen and is illustrated by the Bland-Altman plot (fig 2).

Table 2 shows the ICC for assessment I (manual) and II (dosing chart) for each part of the NAC regimen. This represents the proportion of the total variability between study participants. An ICC of 0% indicates a substantial correction made by the chart, for both doctors and nurses. Likewise, the CVs (table 3) are mostly above 20%.

DISCUSSION

Timely treatment of POD with NAC prevents hepatic failure. For treatment to be safe and effective it is essential that NAC doses are prescribed, prepared and administered accurately. Assuming that the errors identified in this study would have occurred in clinical practice, outcomes may have been compromised in 21 patients (26% (21/80) of cases), 16 of whom would have received underdoses (20%). The chart improved the accuracy

of calculations as evident by the finding that five out of six CVs were >20%, indicating a substantial error reduction. The chart was also well received by the staff who used it.

The study does have limitations. Calculations were performed under "test" conditions away from the usual working environment. These conditions are more likely to have favoured good performance, possibly underestimating the error rate compared to busy clinical practice. Additionally, it is not known whether any of these calculation errors would have been identified and corrected by another nurse, as in clinical practice preparation of the infusion is double checked before administration to the patient. This study focuses on the calculation of NAC doses and volumes and assumes that, in order for patients to receive effective treatment, all other stages in the preparation and administration of infusions—including selection of the diluent, drawing up the Parvolex® volume and setting the infusion rate—are carried out correctly.

Table 1 Accuracy of calculations performed by doctors* and nurses†

NAC regimen	Doctors: number (%) accurate (n = 27)		Nurses: number (%) accurate (n = 53)	
	Assessment I	Assessment II	Assessment I	Assessment II
15 min regimen	26 (96)	27 (100)	41 (77)	53 (100)
4 h regimen	25 (93)	27 (100)	42 (79)	53 (100)
16 h regimen	25 (93)	27 (100)	38 (72)	53 (100)
Entire regimen	76 (94)	81 (100)	121 (76)	159 (100)

*Doctors: 15 senior house officers, 2 junior clinical fellows, 7 specialist registrars, 1 staff grade and 2 consultants, all with a minimum of two months experience (grading in 2005).

†Nurses: grades ranging from D to I (grading in 2005).

Figure 2 Bland-Altman Plot showing the differences between assessments I and II plotted against the average for the two assessments.

Table 2 Intra-class correlation coefficient for each regimen

	15 min regimen (assessment I & II)	4 h regimen (assessment I & II)	16 h regimen (assessment I & II)
Doctors	0% (0% to 38%)	0% (0% to 38%)	0% (0% to 38%)
Nurses	0% (0% to 33%)	0% (0% to 32%)	0.5% (0% to 28%)

Table 3 Coefficients of variation for each regimen

	15 min regimen Assessment		4 h regimen Assessment		16 h regimen Assessment	
	I	II	I	II	I	II
Doctors	20%	0%	20%	0%	13%	0%
Nurses	137%	0%	128%	0%	130%	0%

The prescribing and administration of NAC is a two-step process. In clinical practice, it is possible that if a doctor makes an error in the dose calculation and therefore prescribes an incorrect dose, the error will not be identified by nurses. The prescribing error will then be carried through to the preparation and administration phase unless the prescriber's calculation is rechecked. The dosing chart ensures accuracy of all calculations and facilitates double-checking of the prescription by pharmacists and nurses involved in the pharmaceutical care of the patient.

Conclusion

The NAC dosing chart eliminated calculation errors in the staff tested and appeared to be superior to current practice in ensuring accurate dose and volume calculations. This may translate into improved patient safety and outcome. Since the study, the chart has been modified (fig 1) and incorporated into an integrated POD management pathway in our ED. The effectiveness of this chart in clinical practice is being evaluated.

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