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Puking less per pound, for acute wheezers: quality improvement in a Pediatric Emergency Department

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ABSTRACT

Background & local problem: Acute wheezing attacks are a leading cause of Pediatric Emergency Department (PED) attendances and inpatient admissions and are a considerable burden on the healthcare providers. Almost one-third of children vomit prednisolone in the PED, requiring anti-emetics and repeat dosing.

Aim: This quality improvement (QI) intervention aimed to improve oral corticosteroid (OCS) tolerability, reduce emergency department length of stay (LOS), and reduce OCS drug costs for acute wheeze attendances in a PED, while not adversely affecting admissions, re-attendance, or mortality rates.

QI Interventions: Included (1) a departmental protocol and (2) modification of the OCS type and dosage from prednisolone (3-day course of 1 mg/kg) to dexamethasone (600 mcg/kg, then single dose 300 mcg/kg).

Methods: The study team reviewed the evidence and implemented the interventions. To assess the scale of improvement, we retrospectively collected data on attendance records for patients aged 2-14 years with acute wheeze requiring OCS. We collected data on 100 children who attended the PED between October and December for each year (2016, 2017, and 2018). We then assessed OCS tolerability, LOS, OCS drug costs, and, admission, re-attendance, and mortality rates.

Results: Over a 48-month period, we increased OCS tolerability by 67.2% and achieved an 85.8% reduction in OCS drug costs (saving £41,553.14). There was no change in the LOS, admission, re-attendance, and mortality rates.

Conclusions: Improved tolerability and substantial cost savings can be achieved by implementing a structured acute pediatric wheeze protocol and modifying the OCS to single-dose dexamethasone (300 mcg/kg).

Registration: Not registered

BACKGROUND

Acute wheezing attacks are a leading cause of Pediatric Emergency Department (PED) attendances [1]. Children presenting in respiratory distress, due to asthma attacks or episodic viral wheeze (EVW), often require recurrent bronchodilator therapy, oral corticosteroids (OCSs), continuous assessment, and occasionally, inpatient admission [2-4]. Treatments can be unpleasant, and while early administration of prednisolone, an OCS, is recommended, 28% of children vomit, causing further distress and necessitating repeated dosing or an intravenous or intramuscular alternative [5].

Achieving patient flow is a persistent challenge for PEDs, especially in autumn and winter when viruses are prevalent [6,7]. Vomiting of OCS medications, in addition to being unpleasant, may delay the therapeutic effects, in turn, prolonging the length of stay (LOS) in PEDs. Quality improvement (QI) interventions to tackle these challenges are crucial for improving patient outcomes, experiences, and cost-effectiveness, and are commonly underpinned by research [8,9].

Recently, progress has been made on manufacturing flavoured prednisolone preparations; although more palatable, they would come at extra cost to the healthcare providers [5]. Dexamethasone, a corticosteroid routinely used in childhood croup, has been trialled in acute wheeze as an alternative to prednisolone. Dexamethasone is a glucocorticoid with anti-inflammatory potency seven times greater than prednisolone. It is enterally well absorbed, yielding peak serum concentrations within 1-2 hours, yet, in comparison to prednisolone, dexamethasone has a relatively long half-life of 36-52 hours [10-12]. A systematic review and meta-analysis found a single dose (or 2-dose regime) of dexamethasone to be a viable alternative to a 5-day course of prednisolone, noting patients were less likely to vomit [13]. Cronin *et al*. [14] compared a single-dose oral

dexamethasone (300 mcg/kg) to a three-day course of oral prednisolone (1 mg/kg); reporting no difference in admission rates, unscheduled attendances, or patients' pediatric respiratory assessment measure (PRAM) scores. Dexamethasone may also be more cost-effective, although actual savings are unclear [15,16]. And while structured asthma management protocols have shown some reduction in medication delivery times and hospital LOS [16-18], less is known about the scale of improvement in designated PEDs.

This quality improvement project (QIP) aimed to improve OCS tolerability, reduce LOS in the PED, and reduce OCS drug costs for patients with acute pediatric wheeze in a UK PED, while maintaining admission, re-attendance, and mortality rates. To achieve this, we used a quality improvement framework endorsed by The Institute of Healthcare Improvement (IHI) [19], and based on current evidence, implemented a structured protocol and changed the OCS from prednisolone to dexamethasone.

METHODS

We undertook this QIP in the PED within the Royal Belfast Hospital for Sick Children (RBHSC) over a three-year period (2016-18). We report the study information in-line with the Standards for Quality Improvement Reporting Excellence (SQUIRE) 2.0 and include a checklist (in supplementary file 1) [20].

Contextual information

The RBHSC is a teaching hospital that provides local secondary care to Belfast and tertiary care throughout Northern Ireland (UK). The RBHSC PED provides acute care for over 45,000 children annually, from birth up to 14 years.

The QIP team & procedures

The QIP team included two PED consultants (BB & SM), three PED trainees (GD, BK, & RM), two pediatric respiratory consultants (HS & MDS), two medical students (JR & MT), a pediatric clinical pharmacist (JM), and a statistician (VO).

The aims

This QIP aimed to:

1. Increase the number of children who tolerated OCSs by 70% within 12-months (and maintain this increase for a further 12-months). OCS tolerability was defined as successful OCS ingestion without 'spitting out' during administration or vomiting post-administration while in the department.
2. Reduce LOS by 20% within 12-months (and maintain for a further 12-months). LOS was defined as time from arrival at the PED, to discharge home (and excluded those admitted).

3. No change in hospital admissions, re-attendances, or mortality rates at 12-months (and at 24-months). Hospital admissions (to a medical ward or short-stay unit) and re-attendances (unscheduled, to primary or secondary care) throughout Northern Ireland within seven days of initial attendance were included.
4. Reduce annual OCS drug costs by 80% within 12-months (and maintain for a further 12-months).

Outcome measures (aims 1, 2, and 4) examined the desired impact on patient outcomes, while balancing measures (aim 3) assessed for unintended consequences. Specific targets of 70%, 20%, and 80%, for aims 1,2, and 4, respectively, were based on published evidence and national drug costings [13,17,21].

QI interventions: structured protocol & OSC drug type/dose

In 2016, prior to QI implementation and consistent with national guidance [3,4,21], 1-2 mg/kg of oral prednisolone (maximum 40 mg), in the form of 5 mg soluble tablets, were administered to patients in the PED with the first bronchodilator, with further doses given at home for two consecutive days. In September 2017, we implemented the 'Acute asthma and viral-induced wheeze management protocol' (supplementary file 2), recommending a single 600 mcg/kg dose of oral dexamethasone with the first bronchodilator in the PED. We used an oral solution dexamethasone preparation of 2 mg/5ml concentration, with maximum 16 mg equating to 40 mls. In September 2018, following recent evidence [14], we amended the protocol (supplementary file 3) to a single 300 mcg/kg dose of oral dexamethasone with a repeat 300 mcg/kg dose at admission (16 mg maximum combined). Home dosages of dexamethasone were not prescribed.

Protocols were uploaded onto the PED intranet and project updates were relayed to clinical staff at weekly departmental teaching.

Record identification and selection

Record identification

To identify relevant records, GD used the PED electronic management system (Symphony ®) to extract all records for patients aged 2-14 years who attended for medical assessment with respiratory complaints in October, November, and December of years 2016, 2017, and 2018. Records were randomised using Microsoft Excel prior to formal selection.

Record selection

In October 2019, MT and JR reviewed the randomised list and selected 100 attendance records for each year (2016, 2017, and 2018 (total n=300)) based on the eligibility criteria.

Inclusion Criteria:

1. Attended the RBHSC PED between 1st October 2016 and 31st December 2016, 1st October 2017 to 31st December 2017, or 1st October 2018 to 31st December 2018.
2. Patients aged 2 years and over (to avoid bronchiolitis diagnoses), up to 14 years (the upper departmental age limit).
3. Received OCS treatment for an asthmatic attack or EVW (defined as wheeze caused by a viral infection).

Exclusion Criteria:

1. Discharged home at triage (therefore, not requiring medication).
2. Left the department prior to medical assessment.

Data collection

We extracted information from the PED electronic database (Symphony ®) (MT & JR) and the Northern Ireland Electronic Care Record (NIECR) (BK, GD, & RM) using a bespoke data collection spreadsheet on Microsoft Excel. Symphony ® provided accurate arrival and departure times and complete clinical documentation, whilst the NIECR provided clinical records from primary and other secondary care units throughout Northern Ireland where children may have re-attended.

We assigned patients to moderate or severe/life-threatening severity based on the National Institute Clinical Excellence (NICE) and Scottish Intercollegiate Guideline Network (SIGN) guidelines [3,4]; patients' vital signs (i.e. SpO_2, RR, and HR) and assessment findings (i.e. presence of difficulty speaking in full sentences, confusion, and silent chest) were used to grade severity based on the age-appropriate ranges. As a quality assurance measure, GD reviewed 10% of selected records and resolved any anomalies (such as missing documentation or data irregularities) by accessing original paperwork.

Statistical analysis

OCS tolerability, LOS, admission, re-attendance, and mortality data (aims 1, 2, & 3)

Analysis by year

We undertook two distinct approaches to the analysis. To assess changes in measures over time, we initially analysed data based on the years of attendance, grouping records according to 3 years (2016, 2017, and 2018). We calculated adherence, defined as

administration of the appropriate steroid type (and dosage in respect to dexamethasone) as per protocol for the respective period; for dexamethasone, we allowed for a +/- 10% dosage discrepancy (which is consistent with published literature) [22], and accepted maximum doses of 16 mg as per protocol.

Analysis by OCS drug type and dosage

We noted that some patients in 2016 received dexamethasone, while some patients in 2017 and 2018 received prednisolone. Therefore, to specifically assess the effects of the OCS regime, we grouped records for a second time, based on OCS drug type and dosage. Due to dosage heterogeneity (e.g., 450 mcg/kg of dexamethasone), we selected records within specific limits, which allowed for direct comparisons. All groupings are defined in Box 1.

For brevity purposes, groupings by year were labelled accordingly: 2016, 2017, and 2018. In addition, groupings by actual OCS type and dosage administered, irrespective of year, were labelled: PRED, DEX(600), and DEX(300).

Data was analysed initially (by JR and RM) using Microsoft Excel. Further statistical analysis was completed (by VO) using IBM SPSS Statistics for Windows software, version 26 (IBM Corp., Armonk, N.Y., USA). Results are reported using either mean ± Standard Deviation (SD), or median and Interquartile range, where appropriate. For comparisons between two or more means, one-way analysis of variance (ANOVA) was used. Where data violated the ANOVA assumptions, the non-parametric equivalent Kruskal-Wallis H Test was used. Independent samples t-tests were used to compare means of two continuous variables. A Chi-squared test or Chi-squared test for trend was used to

compare the distribution of categorical variables. For all tests, a p-value < 0.05 was considered to be statistically significant.

Annual OCS drug-cost analysis (aim 4)

We calculated the departmental savings incurred by OCSs (dexamethasone and prednisolone) in 2017 and 2018, compared to 2016. To calculate the number of patients receiving OCSs for acute wheeze annually, we searched Symphony ®, identified all patients presenting with respiratory symptoms in 2019 (January to December), and reviewed clinical documentation of 10 attendances for each month to determine the proportion receiving OSCs. Further detail is available in supplementary file 4.

Study approvals

The Belfast Health and Social Care Trust Audit Offices approved this as a QI intervention and research ethics was not required [23].

Patient and public involvement

Patients and the public were not formally consulted in conceptualisation or design.

RESULTS

Demographics, severity, OCS used, and diagnoses

Three-hundred records, 100 from October to December each year (2016, 2017, and 2018), were randomly selected out of 2,435 potentially eligible (12.3%) children attending the RBHSC PED with respiratory complaints. Two records from 2016 referred to second attendances and were merged to avoid duplication. Data on demographics, severity, OCSs, and diagnoses for 2016, 2017, and 2018 are displayed in Table 1.

The mean age was 4.4 years (range 2 to 14 years), 64% were male, and the most common diagnosis was EVW (57.0%). There was no statistical difference in severity between groups.

Adherence to protocol

There was adherence to the protocol in 80.0% and 90.0% of cases for 2017 and 2018, respectively. Non-adherence was mainly due to the alternative OCS being administered (prednisolone or dexamethasone) and underdosing of dexamethasone. Two cases in 2016 received both prednisolone and dexamethasone. Figure 1 shows OCS treatment administered during 2016, 2017, and 2018.

Outcomes for groupings by year and by OCS drug type and dosage are presented in table 2A and 2B, respectively.

OCS tolerability (aim 1): improved tolerability, aim partly achieved

In 2016, intolerability occurred in 12.2% of patients, compared to 3.0% in 2017, and 5.0% in 2018, (p = 0.057); representing a 75.4% increase in OCS tolerability in the first 12-months and 59.0% in the second 12-months using 2017 and 2018 protocols,

respectively, compared to 2016. Therefore, the target (70% improvement in tolerability) was achieved at 12 months, but not sustained at 24 months. On comparing OCS type and dosages (irrespective of year), vomiting occurred in 10.1% of cases administered PRED compared to 3.6% and 5.8% in DEX(600) and DEX(300), respectively (p = 0.101). Anti-emetic usage was highest in 2017 at 5.0%.

LOS in PED (aim 2): no change, aim not achieved

Mean LOS in the PED was 3.6 hours in 2016, 4.2 hours in 2017, and 3.8 hours in 2018. The target (20% reduction to an average of 2.9 hours) was not achieved for either 2017 and 2018, or for DEX(300) and DEX(600).

Figure 2 illustrates OCS intolerability and LOS in PED, between groupings.

Admission, re-attendance, and mortality rates (aim 3): no change, aim achieved

The lowest admission rate (32.7%) was seen in 2016, followed by 2018 (35.0%), with the highest rate in 2017 (42.0%) (p = 0.363). Admission rates for patients receiving PRED and DEX(300) were similar, at 32.3% and 31.7% respectively; patients given DEX(600) had an admission rate of 45.2% (p = 0.104). There was no significant difference in re-attendance rates between the three years (p = 0.149). The lowest re-attendance rate occurred in 2017; 3 patients reattended and 1 patient required admission at re-attendance. Nine patients reattended in 2016 and 2018; 7 and 0 respectively were admitted at re-attendance. The highest re-attendance rate (10.1%) was for those administered PRED, followed by DEX(300) (8.7%). Patients receiving DEX(600) had the lowest re-attendance rate of 2.4% (p = 0.109). Eight (80.0%) of the re-attending patients that were initially

given PRED required admission, whereas none of the patients given DEX(300) or DEX(600) were admitted after re-attendance. No deaths occurred.

OCS drug costings (aim 4): reduced costs, aim achieved

The PRED regime was most expensive, followed by DEX(600) and DEX(300). For a 10kg child in September 2017, PRED at 1mg/kg (once per day for 3 days) costs £10.68, compared with £1.88 for DEX(600) and £0.94 for DEX(300). Every year, approximately 2,096 patients aged 2-14 present to the PED with respiratory symptoms; approximately 44.16% (n=926) receive OCSs for acute wheeze. Figure 3 illustrates annual departmental OCS drug costs over the 3 years. In 2016, the annual OCS cost of prednisolone, dexamethasone, and both OCSs for acute wheeze amounted to £23,966.02, £190.35, and £24,156.37, respectively. In 2017, the respective cost of prednisolone, dexamethasone, and both OCSs equated to £1,876.18, £2,778.91, and £4,655.09, producing savings of £19,501.28 (80.7%) and therefore achieving the 80% target. In 2018, prednisolone, dexamethasone and both OCSs cost the department £277.40, £1,900.11, and £2,177.51, respectively, resulting in £21,978.87 (90.9%) savings, and achieving the 24-month target for OCS cost.

QIP feedback and challenges

Informal feedback from PED staff was positive; subjectively, juniors found the protocol useful and dexamethasone administration was less arduous for staff and patients. In 2017, general practitioners (GPs), who received patient discharge plans as standard practice, noted the change in OCS treatment and contacted the RBHSC respiratory consultants for general advice.

DISCUSSION

Key Findings

By implementing QI interventions, we increased OCS tolerability by 75.4% within the first 12 months and 59.0% within the second 12 months and achieved accumulative cost savings of £41,480.15 (85.8%) within 24 months. There was no significant difference in the LOS in the PED and low admission, re-attendance, and mortality rates were maintained.

Interpretation

Our findings are consistent with recent evidence, supporting dexamethasone as an alternative to prednisolone for acute wheezing attacks, with better tolerability and cost-effectiveness [14]. Despite our hypothesis, better tolerability did not reduce the LOS; possibly because other factors (i.e., the time of day, day of the week, no. daily attendances, staffing levels, and seniority, etc.) also have an impact on patient flow, which we did not include in our analysis [24]. Non-adherence was mainly due to unfamiliarity with the departmental protocol, rounding up or down of liquid formulations, and confusing the dose with that used for croup (150 mg/kg).

Strengths and limitations

Our study adds to current evidence, because it provides a comprehensive and practical account of evidence-based QI interventions, delivering better tolerability and substantial cost-savings within a PED, and includes direct comparisons on OCS regimes. We took additional steps to ensure data accuracy yet acknowledge the limitations of retrospective data collection on data completeness and continual quality improvement

efforts. Although GPs received patient discharge plans, we acknowledge that direct contact outlining prospective changes should have been made prior to implementation. Furthermore, surveys or similar formal feedback methods would have been informative to the change process, and therefore, should be the focus of future QI efforts.

Recommendations for future practice

We suggest, based on our findings, that PEDs and general EDs could improve tolerability and make significant cost savings using a departmental protocol directing the use of single-dose dexamethasone (300 mg/kg) for children with wheezing attacks; drug tariffs are nationally applicable, although medication costs vary internationally and are subject to pharmaceutical bids. Departments should liaise with ward staff and GPs to create a longer-term management protocol post ED discharge or admission, prior to QI implementation.

CONCLUSION

By implementing a structured acute pediatric wheeze protocol and modifying the OCS type and dose, we reduced vomiting by 67.2% over 24 months and achieved cost savings of £19,501.28 (80.7%) at 12 months and £41,480.15 (90.9%) at 24 months; whilst maintaining LOS, admission, re-attendance, and mortality rates. We would recommend that other departments implement similar QIPs to improve tolerability and reduce costs.

List of abbreviations

cBNF- British National Formulary for Children

ED- Emergency department

EVW- Episodic viral wheeze

GP- General Practitioner

LOS- Length of stay

NICE- National Institute of Clinical Excellence

NIECR- Northern Ireland Electronic Care Record

PED- Pediatric Emergency Department

PRAM- Pediatric Respiratory Assessment Measure

RBHSC- Royal Belfast Hospital for Sick Children

SIGN- Scottish Intercollegiate Guidelines Network

UK- United Kingdom

Ethics approval and consent to participate

Not required as per Health Research Authority regulations.

Consent for publication

Not applicable.

Availability of data and materials

Data available upon request.

Authors' contributions

GD, BB, JM, & HS conceptualised the project. BB, JM, HS, & SM oversaw project execution. GD, JR, MT, RM, & BK collected data and completed provisional analysis. VO completed further statistical analysis. GD & SM supervised data collection and analysis. GD & JR wrote the first draft and all authors contributed to the write-up. SM & MDS provided critical revision. All authors read and approved the final manuscript.

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FIGURE LEGENDS

Figure 1 Oral corticosteroid medication prescribed

Figure 2 Oral corticosteroid (OCS) intolerability (A) and length of stay (LOS) in the Pediatric Emergency Department (PED) (B) for groupings by year, and OCS type and dosage. OCS intolerability, spat-out OSC or vomited after administration while in the PED; LOS in PED, time from arrival until discharge home (excluding admissions).

Figure 3 Annual OCS drug costs (£) for acute wheeze, in the Pediatric Emergency Department in 2016, 2017, and 2018.