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ORIGINAL ARTICLE

Bronchiolitis at a specialist paediatric centre: The electronic medical record helps to evaluate low-value care

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Aim: Low-value care (LVC) is common. We aimed, using infants presenting to a major tertiary paediatric hospital with bronchiolitis between April 2016 and July 2018, to: (i) assess rates of chest X-ray (CXR) and medication use; (ii) identify associated factors; and (iii) measure the harm of not performing these practices.

Methods: We extracted data from the electronic medical record for all children aged 1–12 months given a diagnosis of bronchiolitis in the emergency department. Factors potentially associated with LVC practices were extracted, including patient demographics, ordering physician characteristics, order indication, medications prescribed and admission ward. To assess for harm, a radiologist, blinded to CXR indication, reviewed all CXRs ordered over the winter of 2017 for infants with bronchiolitis.

Results: A CXR was ordered for 439 (11.2%) infants, most commonly to rule out consolidation and collapse (65%). CXRs were more likely to be ordered for admitted infants (40.9% admitted to the general medical ward), and 62% were ordered by emergency department staff. Salbutamol was prescribed for 9.3% ($n = 199$). Amongst those who had a CXR, 28% were prescribed an antibiotic compared to 2.1% for those who did not. In an audit of 98 CXRs ordered over the winter of 2017, there were no CXR findings that meaningfully affected patient outcomes.

Conclusion: Using electronic medical record data, we found that CXR and medication use in bronchiolitis were higher than expected given our hospital guideline advice. Future research needs to understand why and develop interventions to reduce LVC.

Key words: bronchiolitis; electronic medical record; low-value care.

What is already known on this topic

- 1 Bronchiolitis is the most common reason for hospital admission in infants in the first year of life.
- 2 Bronchiolitis is a clinical diagnosis with no effective treatment beyond supportive care; guidelines recommend against the use of routine investigations such as chest X-ray (CXR) or the use of medications such as bronchodilators and antibiotics.
- 3 There is increasing concern world-wide about the need to reduce low-value care practices, and the Royal Australasian College of Physicians, Paediatric and Child Health Division have nominated CXR and medications in bronchiolitis as one of the Evolve criteria, the top 5 'not to do' practices.

What this paper adds

- 1 Despite international guidelines recommending against routine CXR and bronchodilators for infants with a clinical diagnosis of bronchiolitis, high rates of low-value care (CXR 11.2%, bronchodilators 9.2%) continue in a large paediatric teaching hospital.
- 2 CXRs were most commonly ordered to rule out consolidation; however, CXR findings did not correlate with the decision to treat with antibiotics.
- 3 Antibiotics were used more frequently in those for whom a CXR was ordered (28% compared to 5.1%), with rates rising to 59% in those whose indication for CXR was to rule out consolidation or collapse.

Bronchiolitis is the leading cause of hospital admission in infants.¹ In 2017, the Paediatric and Child Health Division of the Royal Australasian College of Physicians nominated the use of chest X-ray (CXR) and medications for bronchiolitis in their Evolve Top 5 practices in

paediatrics² in response to the Choosing Wisely campaign to increase recognition of the harm and costs associated with investigations and treatment that provide little benefit to the patient.³ CXRs in bronchiolitis do not discriminate well between bronchiolitis and pneumonia, with a Canadian study⁴ demonstrating that 133 CXRs needed to be performed for one alternative diagnosis. In this study, antibiotic usage increased five-fold if a CXR was performed. Not only is this a concern in an era of increasing antibiotic resistance, but 1 in 15 infants experience side effects related to antibiotic use.⁴

International Guidelines^{5–7} recommend against the routine use of CXR in bronchiolitis; however, a recent US study demonstrated

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Conflict of interest: None declared.

Accepted for publication 23 July 2019.

rates of at least 42%.⁸ A multi-site study in 2017 involving 38 paediatric emergency departments (EDs) across eight countries, has shown varying rates of CXR, from 1.6% to 81%, with the lowest rates seen in the UK and use in Australasia having an odds ratio of 1.8 compared to the UK.⁹ In US centres where interventions to reduce the rate of CXR-ordering practices have been implemented, rates remain in excess of 20%.¹⁰ In the UK, following the implementation of guidelines reinforced with a clinician educational intervention, one paediatric hospital managed to reduce CXR rates from 12 to 4%.¹¹

World-wide guidelines, updated in 2016, also recommend strongly against the use of bronchodilators in bronchiolitis. Evidence, based on over 2000 participants younger than 1 year of age in 31 randomised controlled trials who presented with bronchiolitis based on clinical symptoms such as cough, wheeze and coryza, demonstrates that harms outweigh benefit.¹² Previous guidelines have recommended trials of bronchodilator therapy; however, subgroup analysis has been unable to identify a cohort likely to respond, and subsequent recommendations advise against the use of bronchodilators in any patient.^{5–7} There is no evidence that these treatments improve important outcomes such as oxygen saturation, hospital admission or time to resolution of illness. In contrast, the use of bronchodilators is associated with significant adverse effects, such as tachycardia, oxygen desaturation and tremors.¹² An Australasian study showed rates of bronchodilator use in patients admitted to hospital with bronchiolitis varying from 27 to 48.7%, increasing with age.¹³

Our institution is a major specialist paediatric hospital with over 85 000 emergency presentations per year and 50 000 inpatient episodes. We produce widely accessed, evidence-based clinical practice guidelines. The introduction of an electronic medical record (EMR) in 2016 has provided access to reliable medication and medical imaging ordering data. We aimed to determine rates of CXR, bronchodilator and antibiotic use in children who received an ED diagnosis of bronchiolitis and factors associated with this low-value care (LVC). We hypothesised that rates of CXR use would be low as this has been a long-standing recommendation at our hospital. Given the association between the use of CXR and higher rates of antibiotics, we expected antibiotic use to also be low. We expected to see an ongoing use of bronchodilators, particularly in children over the age of 6 months given that this is the cohort in which previous guidelines recommended a trial of medication. We expected to see higher rates of interventions (both medications and imaging) in children who were considered more unwell and therefore admitted to the hospital ward compared to those admitted to short-stay units or discharged home from the ED.

Methods

This retrospective study was conducted at The Royal Children's Hospital, Melbourne, Australia.

Infants between 1 and 12 months old who were assigned a diagnosis of bronchiolitis in the ED between April 2016 and July 2018 (2 years 3 months) were included. Patients under 28 days of age were excluded due to CXR being recommended by local guidelines for this age group with a fever and respiratory signs. Patients admitted to the intensive care unit (either neonatal or paediatric) were also excluded.

Outcome measures

The primary outcomes were the percentage of patients who had a CXR ordered or an anti-asthmatic medication or antibiotic prescribed. Our EMR has a classifier for anti-asthmatic medications, which includes salbutamol, adrenaline, ipratropium, prednisolone, dexamethasone, aminophylline and magnesium – the presence of one of these medications resulted in a positive finding for 'anti-asthmatic' medication. However, all infants who received an anti-asthmatic medication also received salbutamol, and thus, we report on salbutamol use in our results. The EMR contains a classifier for antibiotics, and the presence of any antibiotic prescribed during the hospital episode resulted in a positive finding for 'antibiotics'.

Factors associated with ordering behaviours were assessed by extracting data on patient demographics, the main indication for CXR, the ordering department, ordering physician, whether the order was placed within working hours (8–5 pm Monday to Friday) or after hours (5 pm–8 am Monday to Friday and weekends) and admission ward. Length of stay was calculated from the ED presentation time to the hospital discharge time.

A more detailed chart review was performed by the principal investigator (Joanna Lawrence (JL)) on 98 CXRs ordered over winter (June–August) 2017. JL reviewed radiology reports from this period and grouped them into two categories: consistent with bronchiolitis and consistent with consolidation. These categories were compared to the prescription of antibiotics to determine if there was any association between radiologist-reported consolidation and decision to prescribe antibiotics. Order indications (free text in our EMR) for CXR were grouped into seven themes. CXRs were subsequently reviewed for significant findings by a paediatric radiologist. The radiologist was blinded to the indication for the CXR and any other order-specific information.

Data analysis

Rates of interventions (CXR, anti-asthmatics, and antibiotics) and demographic characteristics were calculated from raw data. These were also analysed according to discharge disposition. For categorical data, a two-tailed Fisher's exact test was used, and for continuous data, a Student's *t*-test was used. Odds ratios and 95% confidence intervals were calculated to determine whether patient or clinical factors or timing of ordering were associated with LVC practices. For hypothesis testing, $P < 0.05$ was considered significant.

Results

There were 3897 diagnoses of bronchiolitis made in the ED between April 2016 and July 2018 in a total of 3135 infants. Males accounted for 64.2% of infants, with the average age of presentation being 5.9 months (standard deviation (SD) 3.2 months). The median length of stay in the ED for all patients was 3.0 h (interquartile range 4) with a median length of stay for admitted patients of 35 h (interquartile range 39.0 h). Most infants (56%, $n = 2189$) were discharged home directly from the ED.

CXR use in bronchiolitis

Of presentations with a diagnosis of bronchiolitis in the ED, at least one CXR was ordered for 11.2% (439/3897). Of these, two X-rays were ordered for 45 and three or more were ordered for 18.

In our hospital, the discharge destination for patients with bronchiolitis could be home, the ED-short stay unit for children expected to go home within 24 h, the general medical short stay unit for patients expected to stay 48 h or less, an inpatient ward or hospital in the home for hydration monitoring. The use of CXR by discharge destination is outlined in Table 1, with the lowest proportion seen in those discharged home and the highest in those admitted to the hospital ward.

Junior medical staff ordered 86.5% (380/439) of CXRs, consultants ordered 13.1% (57/439) and nurse practitioners ordered 0.05% (2/439). Emergency staff ordered 61.9% (272/439), with the remainder ordered by ward staff.

Infant age and gender did not differ between those for whom a CXR was ordered and those for whom it was not ($P = 0.57$). Of presentations, 62% (2439/3897) were outside core working hours of Monday to Friday 8 am–5 pm. The percentage of CXRs ordered after hours was also 62.4% (274/439), suggesting the time of presentation was not associated with the decision to order CXR.

Rates of CXR use varied from month to month, with the lowest reported rate at 5.7% (March 2018) and the highest reported rate at 17.5% (January 2018). There was no clear pattern to the variation. There was no difference before and after guidelines were updated in March 2017.

Indications for CXR ordering

Order indications in our EMR are free text. As there are legitimate reasons for ordering a CXR in this population, we

Table 1 Proportions of chest X-ray (CXR) use by discharge disposition

| Discharge disposition | Number receiving CXR, <i>n</i> | Total presentations, <i>n</i> | Presentations ordered a CXR, % |
|------------------------------|--------------------------------|-------------------------------|--------------------------------|
| Home | 71 | 2189 | 3.2 |
| ED short stay unit | 37 | 334 | 11.1 |
| General medical short stay | 112 | 808 | 13.8 |
| General medical ward | 218 | 557 | 39.1 |
| Hospital in the home | 0 | 4 | 0 |
| Transfer to another hospital | 1 | 5 | 20 |
| Total | 439 | 3892 | |

ED, emergency department.

investigated CXR use by indication. An audit of indications for CXR ordered for infants with an ED diagnosis of bronchiolitis during winter 2017 ($n = 98$ CXRs) allowed grouping free-text requests into seven main themes (see Table 2).

Antibiotic use in bronchiolitis

Of all infants with bronchiolitis, 5.1% ($n = 199$) received antibiotics. For those who received antibiotics versus those who did not, length of stay overall was significantly longer (69.1 h (SD 79.2 h) vs. 16.1 h (SD 23.9 h), $P < 0.001$), as was duration of stay in ED (7.2 h (SD 4.8) vs. 4.6 h (SD 4.1), $P < 0.001$).

Of antibiotics prescriptions, 62.8% (125/199) were preceded by a CXR. Among those receiving a CXR, 28.6% (125/439) received antibiotics (rising to 59% in those for whom the indication for CXR was to rule out consolidation/collapse), compared to 2.1% (74/3458) in those without a CXR ($P < 0.001$).

Influence of CXR on antibiotic prescribing

A chart review of stated indications for CXR over winter (June–August 2017) included 70 infants with a total of 98 CXRs ordered (1–3 CXRs per patient). Of the 29 infants prescribed antibiotics, 31% ($n = 9$) of CXRs were reported by a radiologist as suggestive of consolidation, with the remainder (69%, $n = 20$) reported as normal or consistent with viral infection. Of the 41 infants who were not prescribed antibiotics, 19.5% ($n = 8$) were reported as consistent with pneumonia.

There was no significant difference ($P = 0.40$) in treatment decisions between those whose CXR was suggestive of pneumonia and those who had normal findings reported.

Of the 17 with reported consolidation on CXR, 48.1% (8/17) did not receive antibiotics, and no adverse outcomes (deterioration on the ward/repeat admission) occurred.

Risk of harm

A review of the 98 CXRs by the independent study radiologist (Jenny Bracken) found only three CXRs with significant findings. One was a CXR consistent with consolidation. This finding was ignored by the treating team as the child was clinically improving and the consolidation was thought to be viral. The second was a nasogastric tube coiled in the oesophagus. This CXR was ordered to confirm nasogastric tube placement, which is part of our hospital's protocol. The final finding was in a well baby where the parents requested further investigations and the treating doctor

Table 2 Order indications by theme

| Indication | <i>n</i> | % |
|-------------------------------|----------|------|
| Consolidation/Collapse | 67 | 65 |
| Nasogastric tube placement | 14 | 13.5 |
| Foreign body/Aspiration | 8 | 7.8 |
| Pneumothorax | 4 | 3.9 |
| Cardiac size/Pathology | 4 | 3.9 |
| Underlying structural concern | 3 | 2.9 |
| Other | 3 | 2.9 |

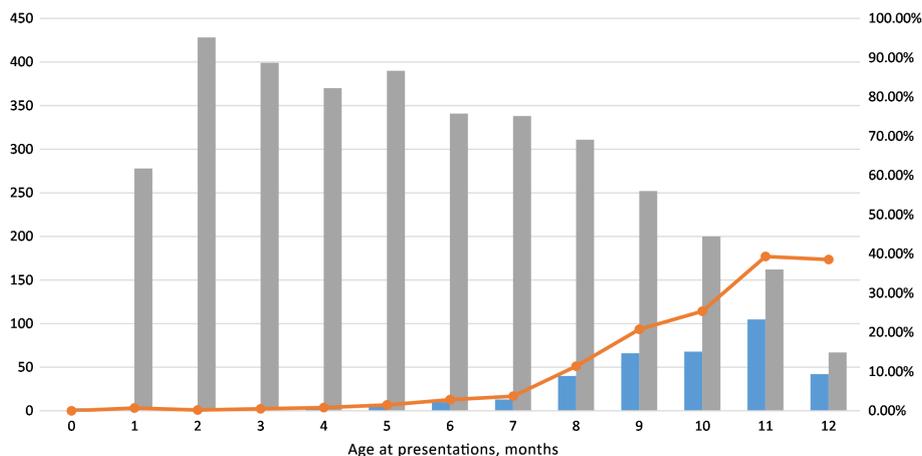


Fig. 1 Percentage of presentations prescribed a bronchodilator by age. (■), Number of encounters with anti-asthmatic medication order; (■), number of encounters without anti-asthmatic medication order; (—●—), Percentage of total: With anti-asthmatic medication order.

complied. This CXR demonstrated an incidental finding of posterior rib fractures. The child was subsequently admitted for a full investigation for non-accidental injury (5 day admission, skeletal survey, bone scan, computed tomography brain, ophthalmology review, blood tests, forensic team involved) with no cause or further abnormalities found.

Salbutamol use in bronchiolitis

Of infants, 9.2% received anti-asthmatic medications, with use increasing from 7 months of age and peaking at 11–12 months at 40% (see Fig. 1). All patients receiving anti-asthmatics received salbutamol. Other anti-asthma medications were prescribed as adjunctive therapy in 13% but were not prescribed in isolation. The length of stay of the infants receiving salbutamol was 29.5 h (SD 33.6 h) compared to 18.8 h (SD 34 h) for those who did not receive salbutamol ($P = 0.001$)

Monthly rates varied from 3.75% (July 2018) to 20.9% (February 2018), with peaks in use each summer. There was no difference in usage after March 2017 when guidelines were updated.

Discussion

Our study highlights the ongoing use of LVC practices in bronchiolitis despite established guidelines in a tertiary teaching hospital. Our hospital publishes evidence-based Clinical Practice Guidelines. Guidelines were updated with new evidence and recommendations in March 2017 against routine CXR and bronchodilator after the publication of the PREDICT guidelines. We report an overall rate of 11.2% of patients receiving a CXR, 9.2% receiving anti-asthmatic medication and 5.1% receiving antibiotics. CXR use was associated with a higher rate of antibiotic prescribing. Approximately half of the infants with CXRs reported as ‘probable consolidation’ did not receive antibiotics with no adverse outcomes. Use of LVC was associated with a longer length of stay.

Our rates of CXR use compare favourably with reported benchmarks in the USA of 20–40%^{10,14} but do not meet those achieved by a UK paediatric centre of 4%.¹¹ Although target rates are difficult to establish, this benchmark study suggests that rates of 4% are achievable and realistic. Our study has demonstrated that reducing rates of CXR to this level would be unlikely to lead

to any significant missed diagnoses but requires replication in other settings.

CXRs ordered for consolidation/collapse are primarily to exclude secondary bacterial pneumonia. In reality, CXR is poor at discriminating between bacterial and viral infections for a number of reasons. First, there is overlap between the findings on CXR in viral and bacterial infections. Specifically, viral infections frequently result in atelectasis secondary to airway obstruction, which can be difficult to distinguish from focal consolidation due to bacterial pneumonia.^{15,16} Second, it may be challenging to obtain a true inspiratory CXR in some infants, and suboptimal inspiratory effort can result in findings on CXR, which mimic lung pathology.¹⁷ Third, there is a degree of subjectivity associated with the interpretation of CXRs, even amongst experienced radiologists.^{16,18,19}

Our results highlight earlier findings⁴ of increased antibiotic prescription following CXR with a greater 10-fold rise in antibiotic use after CXR. This has implications for antibiotic stewardship and potential unnecessary side effects.

In addition, CXRs in bronchiolitis contribute to unnecessary radiation in a cohort of children who are at the beginning of their lifetime cumulative dosage and create workload for radiographers, radiologists, medical staff and ancillary staff, as well as have considerable cost.

Our rates of salbutamol use are lower than previous reports in the Australasian context¹³ but remain higher than expected given the strong recommendation. Although evidence in subgroups remains weak,¹² the number needed to treat and lack of evidence for reduction in needing oxygen use or improvement in hospital length of stay has led to the strong recommendation not to use CXR in any subgroup.

Our study is strengthened by the ability to analyse LVC practices in a large volume of patients. As it is reproducible, change over time can be easily measured and incorporated into audit and feedback tools for front-line clinicians as a key intervention to reduce LVC. We also considered potential harm arising from missed diagnoses through the review of 98 CXRs by a radiologist blinded to the order indication or report. This provides reassurance that a change in practice is unlikely to result in significant missed diagnoses.

However, our study has some limitations. All EMR data rely on accurate input from clinicians. We used the EMR ED discharge

diagnosis of 'bronchiolitis' to identify the patient cohort. Other ED diagnosis categories, such as 'viral infection', 'wheeze' and 'poor feeding', may have been applied by the clinician. Because of this, our data are likely to under-represent the true population of infants presenting to our hospital with bronchiolitis. A further limitation of this study design is the inability to draw casual associations given the cross-sectional nature of the data.

This study demonstrates significant variation from evidence-based practice in a tertiary academic paediatric centre. Next steps for our institution will include an audit and feedback tool for front-line clinicians providing their own data against benchmarks to promote more reflective ordering practices. As with any guideline, implementation must be supported by education and peer support to junior doctors to ensure evidence-based medicine is provided to all patients. Given the strong recommendation around bronchodilator use, a pop-up decision support message in the EMR will be instituted and monitored for effect. Pop-up decision aids in the EMR have proven to be successful and cost-effective interventions in other emergency presentations²⁰ and are widely used in many systems to support safe prescribing practices.²¹ The main risk to this intervention is alert fatigue resulting from a high frequency of alerts and leading to clinician frustration and a tendency to ignore all alerts, even those that present critical safety information.²¹ Alert usage will be closely monitored following implementation. Clinicians at our hospital tend to underuse the bronchiolitis EMR workflow, and as such, we would be reliant on an alert for all infants under 1 year of age. Such an alert will be difficult to implement in order to reduce CXR ordering because there are many valid indications for CXR in infants outside of bronchiolitis (e.g. cardiac, congenital defects, neuromuscular conditions).

Moreover, the ability to continuously audit by running the same report monthly will allow us to easily measure change and effectiveness of interventions. The EMR has proven itself invaluable in analysing LVC practices at our institution.

Interventions targeting parental expectations (e.g. shared care decision supports around LVC practices) and clinician fear of litigation (e.g. statements from the hospital executive supporting clinicians to not conduct LVC practices) may also need to be implemented and evaluated if we are to reduce LVC practices in our hospitals. Importantly, this project has demonstrated the power of EMR to analyse large datasets.

Acknowledgements

Murdoch Children's Research Institute is supported by the Victorian Government's Operational Infrastructure Support Program. H Hiscock is supported by an NHMRC Practitioner Fellowship (1136222). JG Lawrence and T Marshall are supported by a Choosing Wisely grant through Better Care Victoria.

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