Appropriateness of Hospital Admission for Emergency Department Patients with Bronchiolitis: Secondary Analysis

Gang Luo¹, PhD; Michael D Johnson², MD; Flory L Nkoy², MD, MS, MPH; Shan He³, PhD; Bryan L Stone², MD, MS
¹Department of Biomedical Informatics and Medical Education, University of Washington, UW Medicine South Lake Union, 850 Republican Street, Building C, Box 358047, Seattle, WA 98195, USA
²Department of Pediatrics, University of Utah, 100 N Mario Capecchi Drive, Salt Lake City, UT 84113, USA
³Homer Warner Research Center, Intermountain Healthcare, 5121 South Cottonwood Street, Murray, UT 84107, USA
luogang@uw.edu, mike.johnson@hsc.utah.edu, flory.nkoy@hsc.utah.edu, Shan.He@imail.org, bryan.stone@hsc.utah.edu

Corresponding author:
Gang Luo, PhD
Department of Biomedical Informatics and Medical Education, University of Washington, UW Medicine South Lake Union, 850 Republican Street, Building C, Box 358047, Seattle, WA 98195, USA
Phone: 1-206-221-4596
Fax: 1-206-221-2671
Email: luogang@uw.edu
Abstract

**Background:** Bronchiolitis is the leading cause of hospitalization in children under 2 years of age. Each year in the United States, bronchiolitis results in 287,000 emergency department visits, 32%-40% of which end in hospitalization. Frequently, emergency department disposition decisions (to discharge or to hospitalize) are made subjectively because of a lack of evidence and objective criteria for bronchiolitis management, leading to significant practice variation, wasted healthcare use, and suboptimal outcomes. At present, no operational definition of appropriate hospital admission for emergency department patients with bronchiolitis exists. Yet, such a definition is essential for assessing care quality and building a predictive model to guide and standardize disposition decisions. Our prior work provided a framework of such a definition using two concepts, one on safe vs. unsafe discharge and another on necessary vs. unnecessary hospitalization.

**Objective:** The goal of this study is to determine the two threshold values used in the two concepts, with one value per concept.

**Methods:** Using Intermountain Healthcare data from 2005-2014, we examined the distributions of several relevant attributes of emergency department visits by children under age two for bronchiolitis. Via a data-driven approach, we determined the two threshold values.

**Results:** We completed the first operational definition of appropriate hospital admission for emergency department patients with bronchiolitis. Appropriate hospital admissions include actual admissions with exposure to major medical interventions for more than six hours, as well as actual emergency department discharges followed by an emergency department return within 12 hours ending in admission for bronchiolitis. Based on the definition, 0.96% (=221/23,125) of emergency department discharges were deemed unsafe. 14.36% (=432/3,008) of hospital admissions from the emergency department were deemed unnecessary.

**Conclusions:** Our operational definition can define the prediction target for building a predictive model to guide and improve emergency department disposition decisions for bronchiolitis in the future.

**Keywords:** Bronchiolitis; appropriate hospital admission; emergency department; operational definition

1. **Introduction**

Bronchiolitis is inflammation of the bronchioles, the smallest air passages in the lungs, mainly seen in children under age two in response to viral respiratory infection. More than 1/3 of children are diagnosed with bronchiolitis before age two [1]. Bronchiolitis is the leading cause of hospitalization in children under age two and is responsible for 16% of hospitalizations in this age group [2-5]. Each year in the United States, bronchiolitis incurs about 287,000 emergency department (ED) visits [6], 128,000 hospitalizations [2], and US $1.73 billion of total inpatient cost (2009) [2].

Around 32%-40% of ED visits for bronchiolitis end in hospitalization [7-9]. As acknowledged in current clinical guidelines for bronchiolitis [10, 11], ED disposition decisions (to discharge or to hospitalize) are often made subjectively because of a lack of evidence and objective criteria for bronchiolitis management [4, 12]. This causes large practice variation [3, 12-23], wasted healthcare use, increased iatrogenic risk, and suboptimal outcomes due to unnecessary admissions and unsafe discharges [15, 21, 24]. About 10% of infants with bronchiolitis experience adverse events during hospitalization [25]. At present, no operational definition of appropriate hospital admission for ED patients with bronchiolitis exists [26]. Yet, such an operational definition is essential for assessing ED care quality and building a predictive model to guide and standardize disposition decisions [26].

Our prior work [26] provided a framework of such an operational definition using two concepts, one on safe vs. unsafe discharge and another on necessary vs. unnecessary hospitalization (Figure 1). Each concept uses a threshold value to be determined. Appropriate admissions include both necessary admissions (actual admissions that are necessary) and unsafe discharges. Appropriate ED discharges include both safe discharges and unnecessary admissions. This study aims to determine
the two threshold values in a data-driven way, complete the first operational definition of appropriate hospital admission for ED patients with bronchiolitis, and report the corresponding percentages of unnecessary admissions and unsafe discharges.

2. Methods

Study design and ethics approval

This study performed secondary analysis of retrospective data. The institutional review boards of University of Washington Medicine, University of Utah, and Intermountain Healthcare reviewed and approved this study, and waived the need for informed consent for all patients.

Patient population

Our patient cohort included children under age two who had ED encounters at 22 Intermountain Healthcare hospitals for bronchiolitis in 2005-2014. Intermountain Healthcare is the largest healthcare system in Utah, with 185 clinics and 22 hospitals providing ~85% of pediatric care given in Utah [27]. We used an approach similar to those by Flaherman et al. [28-30] to identify as many ED encounters for bronchiolitis as possible.

Several ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification) discharge diagnosis codes, rather than only the discharge diagnosis code of bronchiolitis, can be possibly assigned to an ED encounter for bronchiolitis. Using the methods used in prior studies [28-30], we included patients with an ED or hospital ICD-9-CM primary discharge diagnosis of bronchiolitis or bronchitis (466.x), viral pneumonia (480.x), adenoviral infection (079.0), rhinovirus infection (079.3), respiratory infection due to influenza (487.0, 487.1), respiratory syncytial virus (079.6), H1N1 influenza (488.1, 488.11, 488.12), influenza due to identified avian influenza virus (488, 488.0, 488.01, 488.02), or influenza due to novel influenza A (488.81, 488.82).

We also included all patients with any of the above as a non-primary diagnosis, as long as the ICD-9-CM primary diagnosis is any of the following: apnea (786.03), shortness of breath (786.05), tachypnea (786.06), wheezing (786.07), other respiratory abnormalities (786.09), cough (786.2), fever (780.60, 780.61), acute nasopharyngitis (460), acute upper respiratory infections (465.x), other specified viral infection (079.89), urinary tract infection (599.0), pneumonia unspecified organism (486), unspecified viral infection (079.99), volume depletion (276.5x), or respiratory failure (518.81, 518.82).

Data set

We extracted a clinical and administrative data set from Intermountain Healthcare’s enterprise data warehouse. The data set included ED visit and hospitalization information of our patient cohort.

Data analysis

To determine the threshold value used for defining unsafe discharges (Figure 1), we examined the length distribution of the interval between an ED discharge and a return ED visit within two weeks ending in hospitalization for bronchiolitis [31, 32]. In children under age two, bronchiolitis lasting longer than two weeks tends to result from new infection with a differing virus strain instead of persistent infection by the same virus strain [33].

To determine the threshold value used for defining unnecessary admissions (Figure 1), we examined the patients who were hospitalized for ≤12 hours and discharged with no readmission for bronchiolitis within two weeks. These patients tend to have been admitted unnecessarily. We use their median duration of using major medical interventions as a conservative threshold for using major medical interventions in all admissions. As shown in Figure 1, major medical interventions include “supplemental oxygen, intravenous fluids, nasopharyngeal suctioning, cardiovascular support, invasive positive pressure ventilation (mechanical ventilation), non-invasive positive pressure ventilation, chest physiotherapy, inhaled therapy (bronchodilator and mucolytics), and nutritional support (enteral feeding and total parenteral nutrition)” [26]. Every hospital admission with exposure to major medical interventions for no longer than the threshold is deemed unnecessary. During 2005-2012, Intermountain Healthcare iteratively modified its internal guidelines for bronchiolitis management in the ED and hospital several times, with an associated change in the distribution of the duration of using major medical interventions. After the beginning of 2013, significant changes in internal guidelines did not occur. The duration of using major medical interventions became stabilized. To compute the threshold value, we used 2013-2014 data with a stable distribution of the duration of using major medical interventions. Both the duration of hospitalization and duration of using major medical interventions included only time in the hospital after the patient left the ED.

3. Results

Table 1 shows the demographic and clinical characteristics of our patient cohort: children under age two who had ED encounters for bronchiolitis. About 38.20% (=14,292/37,417) of ED visits for bronchiolitis ended in hospitalization.

| Table 1. Demographic and clinical characteristics of our patient cohort. |
### Characteristic ED visits (n = 37,417) ED visits discharged (n = 23,125) ED visits ending in hospitalization (n = 14,292)

| Characteristic                          | ED visits (n = 37,417) | ED visits discharged (n = 23,125) | ED visits ending in hospitalization (n = 14,292) |
|----------------------------------------|------------------------|-----------------------------------|-----------------------------------------------|
| Age                                    |                        |                                   |                                               |
| <2 months                              | 4,769 (12.75%)         | 1,646 (7.12%)                     | 3,123 (21.85%)                               |
| 2 to <12 months                        | 22,101 (59.07%)        | 14,569 (63.00%)                   | 7,532 (52.70%)                               |
| 12 to 24 months                        | 10,547 (28.19%)        | 6,910 (29.88%)                    | 3,637 (25.45%)                               |
| Gender                                 |                        |                                   |                                               |
| Male                                   | 21,536 (57.56%)        | 13,399 (57.94%)                   | 8,137 (56.93%)                               |
| Female                                 | 15,881 (42.44%)        | 9,733 (42.06%)                    | 6,155 (43.07%)                               |
| Race                                   |                        |                                   |                                               |
| American Indian or Alaska native       | 458 (1.22%)            | 295 (1.28%)                       | 163 (1.14%)                                  |
| Asian                                  | 395 (1.06%)            | 222 (0.96%)                       | 173 (1.21%)                                  |
| Black or African American              | 1,017 (2.72%)          | 664 (2.87%)                       | 353 (2.47%)                                  |
| Native Hawaiian or other Pacific islander | 2,209 (5.90%)        | 1,243 (5.38%)                     | 966 (6.76%)                                  |
| White                                  | 28,510 (76.20%)        | 17,660 (76.37%)                   | 10,850 (75.92%)                              |
| Unknown or not reported                | 4,828 (12.90%)         | 3,041 (13.15%)                    | 1,787 (12.50%)                               |
| Ethnicity                              |                        |                                   |                                               |
| Hispanic                               | 9,011 (24.08%)         | 5,975 (25.84%)                    | 3,036 (21.24%)                               |
| Non-Hispanic                           | 18,823 (50.31%)        | 11,278 (48.77%)                   | 7,545 (52.79%)                               |
| Unknown or not reported                | 9,583 (25.61%)         | 5,872 (25.39%)                    | 3,711 (25.97%)                               |
| Insurance                              |                        |                                   |                                               |
| Private                                | 22,162 (59.23%)        | 13,052 (56.44%)                   | 9,110 (63.74%)                               |
| Public                                 | 13,448 (35.94%)        | 8,729 (37.75%)                    | 4,719 (33.02%)                               |
| Self-paid or charity                   | 1,807 (4.82%)          | 1,344 (5.81%)                     | 463 (3.24%)                                  |
| Asthma                                 | 2,246 (6.00%)          | 883 (3.82%)                       | 1,363 (9.54%)                                |
| Chronic complex condition [34]         | 2,040 (5.45%)          | 365 (1.58%)                       | 1,675 (11.72%)                               |

**Figure 2.** Cumulative length distribution of interval between emergency department discharge and return visit within 2 weeks ending in hospitalization for bronchiolitis.
Figures 2 and 3 show the cumulative distribution of the length in hours of the interval between an ED discharge and a return ED visit within two weeks ending in hospitalization for bronchiolitis. Figure 4 shows the probability density function of the interval length. The probability density function is relatively large until the interval length reaches the cumulative distribution curve’s inflection point at about 10 to 12 hours, and then becomes smaller afterward. The cumulative distribution curve seems to have two inflection points, suggesting three underlying distributions. As indicated by the dotted curve in Figure 4, the three distributions are postulated to represent an early ED return after an inappropriate ED discharge, natural disease progression in a subgroup of appropriate ED discharges, and an even later ED return due to a new viral infection after an appropriate ED discharge, respectively. When selecting the threshold value for defining unsafe discharges (Figure 1), we wanted our choice to capture the majority of unsafe discharges, while avoiding contamination with ED returns not due to unsafe discharges. To help make the choice, we used the probability density function that has a local minimum at the interval length of 10 to 12 hours. We chose 12 hours that fulfilled our selection criteria. Accordingly, 0.96% (=221/23,125) of ED discharges were followed by an ED return within 12 hours resulting in hospital admission for bronchiolitis and are deemed unsafe ED discharges.
In 2013-2014, no major medical intervention was applied in 6.45% (=194/3,008) of cases of hospitalization from the ED for bronchiolitis. In another 7.91% (=238/3,008) of cases, one or more major medical interventions were applied, but the duration of using them was ≤6 hours. Among the patients hospitalized in 2013-2014, 8.31% (=250/3,008) were hospitalized for ≤12 hours and discharged with no readmission for bronchiolitis within two weeks. Figure 5 shows the distribution of the duration in hours of using major medical interventions in these patients. The median duration of using major medical interventions is 6 hours, which we used as the threshold value for defining unnecessary admissions (Figure 1). Accordingly, 14.36% (=432/3,008) of hospital admissions from the ED in 2013-2014 incurred exposure to major medical interventions for no longer than this threshold and were deemed unnecessary.

By filling in the two threshold values in our definition framework (Figure 1) [26], we completed the first operational definition of appropriate hospital admission for ED patients with bronchiolitis. Appropriate hospital admissions include actual admissions with exposure to major medical interventions for more than six hours, as well as actual ED discharges followed by
In the future, it would be desirable to use data from other healthcare systems to validate our operational definition of appropriate hospital admission for ED patients with bronchiolitis. The definition uses two concepts, one on safe vs. unsafe discharge and another on necessary vs. unnecessary hospitalization. Based on our findings, we found that many ED disposition decisions for bronchiolitis were deemed inappropriate. Our findings highlight opportunities for improving ED disposition decisions and the need to build a model to predict appropriate admission. The model could become the foundation of a decision support tool to help make appropriate ED disposition decisions for bronchiolitis, improve bronchiolitis outcomes, and cut healthcare costs [26]. Although the model could be built without using the ED physician’s initial, tentative disposition decision as an input variable, the model would likely be more accurate if this variable is included. In either case, the physician can use the model’s output to give a second thought on his/her initial, tentative disposition decision.

Comparison with prior work
Some aspects of our findings are similar to those in previous studies. In our data set, about 38.20% (=14,292/37,417) of ED visits for bronchiolitis ended in hospitalization. This percentage is close to the corresponding percentages 32%-40% reported in the literature [7-9]. For 30 EDs in 15 U.S. states, Norwood et al. [35] presented the length distribution of the interval between an ED discharge and a return ED or clinic visit within two weeks for bronchiolitis. That distribution is similar to the one we show in Figure 2 on the length of the interval between an ED discharge and a return ED visit within two weeks ending in hospitalization for bronchiolitis.

Some of our findings are different from those in previous studies. In our data set, 14.36% (=432/3,008) of hospital admissions from the ED in 2013-2014 were deemed unnecessary. This percentage is smaller than the corresponding percentages 20%-29% suggested in the literature [36, 37]. Intermountain Healthcare has multiple collaborative partnerships among its EDs and hospitals to ensure that pediatric specialty care is coordinated and not focused just in a tertiary pediatric hospital. Several quality improvement projects for bronchiolitis management were completed during 2005-2012, impacting the ED and hospital care of children in multiple hospitals within Intermountain Healthcare. The average quality of the ED disposition decisions for bronchiolitis made at Intermountain Healthcare could be higher than that at some other healthcare systems, particularly if those healthcare systems employ few pediatricians in their EDs.

Principal results
We completed the first operational definition of appropriate hospital admission for ED patients with bronchiolitis. The definition gives two concepts, one on safe vs. unsafe discharge and another on necessary vs. unnecessary hospitalization. Based on the definition, we found that many ED disposition decisions for bronchiolitis were deemed inappropriate. Our findings highlight opportunities for improving ED disposition decisions and the need to build a model to predict appropriate admission. The model could become the foundation of a decision support tool to help make appropriate ED disposition decisions for bronchiolitis, improve bronchiolitis outcomes, and cut healthcare costs [26]. Although the model could be built without using the ED physician’s initial, tentative disposition decision as an input variable, the model would likely be more accurate if this variable is included. In either case, the physician can use the model’s output to give a second thought on his/her initial, tentative disposition decision.

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Limitations
This study has several limitations. One limitation is that the study used data from a single healthcare system, Intermountain Healthcare, and our results may not generalize to other healthcare systems. Notably, most Intermountain Healthcare hospitals are at high elevation (more than 4,000 feet above sea level). This may result in increased incidence of hypoxia. About 46% of patients hospitalized with bronchiolitis at Intermountain Healthcare are discharged on home oxygen for outpatient management. Protocols are in place to facilitate brief hospitalizations if oxygen is the only intervention a patient needs in the hospital [30]. In the future, it would be desirable to use data from other healthcare systems to validate our operational definition of appropriate hospital admission for ED patients with bronchiolitis. As indicated by the similarities between our findings and those in previous studies, we do not expect such validation to significantly change our results. Intermountain Healthcare is a large healthcare system with EDs at 22 heterogeneous hospitals spread over a large geographic area, “ranging from community metropolitan and rural hospitals attended by general practitioners and family doctors with constrained pediatric resources to tertiary care children’s and general hospitals in urban areas attended by sub-specialists” [26]. Each hospital has a different patient population, geographic location, staff composition, scope of services, and cultural background. This variation provides a realistic situation for finding factors generalizable to other hospitals across the United States.

Another limitation of this study is that Intermountain Healthcare does not have complete clinical and administrative data on all of its patients, although it is an integrated healthcare system. Within two weeks of a visit to an Intermountain Healthcare ED for bronchiolitis, a patient could use a non-Intermountain Healthcare hospital for bronchiolitis again. If this occurred, our data set would miss the information on healthcare use that occurred at the non-Intermountain Healthcare hospital. Including data from non-Intermountain Healthcare hospitals may lead to different results. Nevertheless, we do not expect this to greatly change our results’ accuracy. Intermountain Healthcare provides ~85% of pediatric care given in Utah [27]. Thus, our data set is reasonably, although not 100%, complete in terms of capturing bronchiolitis patients’ use of hospitals at Utah.

A third limitation is that this study does not consider factors such as preference of the patient’s parents, patient transportation availability, and time of day in defining appropriate hospital admission. Many of these factors are often undocumented in patient records. For some hospital admissions from the ED that were deemed unnecessary based on our operational definition of appropriate hospital admission, the original admission decisions could be made due to these factors.
5. Conclusions
We provided the first operational definition of appropriate hospital admission for ED patients with bronchiolitis. Our operational definition can define the prediction target for building a predictive model in the future, with the goal of standardizing and improving ED disposition decisions for bronchiolitis.

Authors’ contributions
GL was mainly responsible for the paper. He conceptualized and designed the study, performed literature review and data analysis, and wrote the paper. BS, MJ, and FN provided feedback on various medical issues, contributed to conceptualizing the presentation, and revised the paper. SH took part in retrieving the Intermountain Healthcare data set and interpreting its detected peculiarities. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Conflicts of Interest
None declared.

List of abbreviations:
- ED: emergency department
- ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification

References
1. Zorc JJ, Hall CB. Bronchiolitis: recent evidence on diagnosis and management. Pediatrics 2010;125(2):342-9. PMID:20100768
2. Hasegawa K, Tsugawa Y, Brown DF, Mansbach JM, Camargo CA Jr. Trends in bronchiolitis hospitalizations in the United States, 2000-2009. Pediatrics 2013;132(1):28-36. PMID:23733801
3. Mansbach JM, Emond JA, Camargo CA Jr. Bronchiolitis in US emergency departments 1992 to 2000: epidemiology and practice variation. Pediatr Emerg Care 2005;21(4):242-7. PMID:15824683
4. Parker MJ, Allen U, Stephens D, Lalani A, Schuh S. Predictors of major intervention in infants with bronchiolitis. Pediatr Pulmonol 2009;44(4):358-63. PMID:19283838
5. Shay DK, Holman RC, Newman RD, Liu LL, Stout JW, Anderson LJ. Bronchiolitis-associated hospitalizations among US children, 1980-1996. JAMA 1999;282(15):1440-6. PMID:10535434
6. Hasegawa K, Tsugawa Y, Brown DF, Mansbach JM, Camargo CA Jr. Temporal trends in emergency department visits for bronchiolitis in the United States, 2006 to 2010. Pediatr Infect Dis J 2014;33(1):11-8. PMID:23934206
7. Marlais M, Evans J, Abrahamson E. Clinical predictors of admission in infants with acute bronchiolitis. Arch Dis Child 2011;96(7):648-52. PMID:21339199
8. Laham FR, Trott AA, Bennett BL, Koziinetz CA, Jewell AM, Garofalo RP, Piedra PA. LDH concentration in nasal-wash fluid as a biochemical predictor of bronchiolitis severity. Pediatrics 2010;125(2):e225-33. PMID:20100751
9. Corneli HM, Zorc JJ, Holubkov R, Bregstein JS, Brown KM, Mahajan P, Kuppermann N; Bronchiolitis Study Group for the Pediatric Emergency Care Applied Research Network. Bronchiolitis: clinical characteristics associated with hospitalization and length of stay. Pediatr Emerg Care 2012;28(2):99-103. PMID:22270499
10. Scottish Intercollegiate Guidelines Network. Bronchiolitis in children. A national clinical guideline. https://www.guidelinecentral.com/summaries/bronchiolitis-in-children-a-national-clinical-guideline/. Archived at http://www.webcitation.org/6bhQvWHzA
11. Bronchiolitis Guideline Team, Cincinnati Children's Hospital Medical Center: Evidence-based care guideline for management of first time episode bronchiolitis in infants less than 1 year of age. http://www.guideline.gov/content.aspx?id=34411. Archived at http://www.webcitation.org/6bhOyj1TC
12. Brand PL, Vaessen-Verberne AA. Differences in management of bronchiolitis between hospitals in the Netherlands. Eur J Pediatr 2000;159(5):343-7. PMID:10834519
13. Ducharme FM. Management of acute bronchiolitis. BMJ 2011;342:d1658. PMID:21471173
14. Behrendt CE, Decker MD, Burch DJ, Watson PH. International variation in the management of infants hospitalized with respiratory syncytial virus. Eur J Pediatr 1998;157(3):215-20. PMID:9537488
15. Chamberlain JM, Patel KM, Pollack MM. Association of emergency department care factors with admission and discharge decisions for pediatric patients. J Pediatr 2006;149(5):644-9. PMID:17095336

16. Johnson DW, Adair C, Brant R, Holmwood J, Mitchell I. Differences in admission rates of children with bronchiolitis by pediatric and general emergency departments. Pediatrics 2002;110(4):e49. PMID:12359822

17. Mallory MD, Shay DK, Garrett J, Bordley WC. Bronchiolitis management preferences and the influence of pulse oximetry and respiratory rate on the decision to admit. Pediatrics 2003;111(1):e45-51. PMID:12509594

18. Plint AC, Johnson DW, Wiebe N, Bulloch B, Pusic M, Joubert G, Pianosi P, Turner T, Thompson G, Klassen TP. Practice variation among pediatric emergency departments in the treatment of bronchiolitis. Acad Emerg Med 2004;11(4):353-60. PMID:15064208

19. Vogel AM, Lennon DR, Harding JE, Pinnock RE, Graham DA, Grimwood K, Pattemore PK. Variations in bronchiolitis management between five New Zealand hospitals: can we do better? J Paediatr Child Health 2003;39(1):40-5. PMID:12542811

20. Willson DF, Horn SD, Hendley JO, Smout R, Gassaway J. Effect of practice variation on resource utilization in infants hospitalized for viral lower respiratory illness. Pediatrics 2001;108(4):851-5. PMID:11581435

21. Willson DF, Jiao JH, Hendley JO, Donowitz L. Invasive monitoring in infants with respiratory syncytial virus infection. J Pediatr 1996;128(3):357-62. PMID:8774504

22. Wang EE, Law BJ, Boucher FD, Stephens D, Robinson JL, Dobson S, Langley JM, McDonald J, MacDonald NE, Mitchell I. Pediatric Investigators Collaborative Network on Infections in Canada (PICNIC) study of admission and management variation in patients hospitalized with respiratory syncytial virus lower respiratory tract infection. J Pediatr 1996;129(3):390-5. PMID:8804328

23. Christakis DA, Cowan CA, Garrison MM, Molteni R, Marcuse E, Zerr DM. Variation in inpatient diagnostic testing and management of bronchiolitis. Pediatrics 2005;115(4):878-84. PMID:15805359

24. Mansbach JM, Clark S, Christopher NC, LoVecchio F, Kunz S, Acholonu U, Camargo CA Jr. Prospective multicenter study of bronchiolitis: predicting safe discharges from the emergency department. Pediatrics 2008;121(4):680-8. PMID:18381531

25. McBride SC, Chiang VW, Goldmann DA, Landrigan CP. Preventable adverse events in infants hospitalized with bronchiolitis. Pediatrics 2005;116(3):603-8. PMID:16140699

26. Luo G, Stone BL, Johnson MD, Nkoy FL. Predicting appropriate admission of bronchiolitis patients in the emergency department: rationale and methods. JMIIR Res Protoc 2016;5(1):e41. PMID:26952700

27. Byington CL, Reynolds CC, Korgenski K, Sheng X, Valentine KJ, Nelson RE, Daly JA, Osguthorpe RJ, James B, Savitz L, Pavia AT, Clark EB. Costs and infant outcomes after implementation of a care process model for febrile infants. Pediatrics 2012;130(1):e16-24. PMID:22732178

28. Flaherman VJ, Ragins AI, Li SX, Kipnis P, Masaquel A, Escobar GJ. Frequency, duration and predictors of bronchiolitis episodes of care among infants ≥32 weeks gestation in a large integrated healthcare system: a retrospective cohort study. BMC Health Serv Res 2012;12:144. PMID:22682080

29. Mittal V, Darnell C, Walsh B, Mehta A, Badawy M, Morse R, Pop R, Tidwell J, Sheehan M, McDermott S, Cannon C, Kahn J. Inpatient bronchiolitis guideline implementation and resource utilization. Pediatrics 2014;133(3):e730-7. PMID:24534398

30. Sandweiss DR, Mundorff MB, Hill T, Wolfe D, Greene T, Andrews S, Glasgow TS. Decreasing hospital length of stay for bronchiolitis by using an observation unit and home oxygen therapy. JAMA Pediatr 2013;167(5):422-8. PMID:23479000

31. Halfon P, Eggli Y, van Melle G, Chevalier J, Wasserfallen JB, Burnand B. Measuring potentially avoidable hospital readmissions. J Clin Epidemiol 2002;55(6):573-87. PMID:12063099

32. Heggstad T, Lilleeng SE. Measuring readmissions: focus on the time factor. Int J Qual Health Care 2003;15(2):147-54. PMID:12705708

33. Jartti T, Lee WM, Pappas T, Evans M, Lemanske RF Jr, Gern JE. Serial viral infections in infants with recurrent respiratory illnesses. Eur Respir J 2008;32(2):314-20. PMID:18448489

34. Feudtner C, Feinstein JA, Zhong W, Hall M, Dai D. Pediatric complex chronic conditions classification system version 2: updated for ICD-10 and complex medical technology dependence and transplantation. BMC Pediatr 2014;14:199. PMID:25102958

35. Norwood A, Mansbach JM, Clark S, Waseem M, Camargo CA Jr. Prospective multicenter study of bronchiolitis: predictors of an unscheduled visit after discharge from the emergency department. Acad Emerg Med 2010;17(4):376-82. PMID:20370776

36. Shaw KN, Bell LM, Sherman NH. Outpatient assessment of infants with bronchiolitis. Am J Dis Child 1991;145(2):151-5. PMID:1994678
37. Shafik MH, Seoudi TM, Raway TS, Al Harbash NZ, Ahmad MM, Al Mutairi HF. Appropriateness of pediatric hospitalization in a general hospital in Kuwait. Med Princ Pract 2012;21(6):516-21. PMID:22678120