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REVIEW ARTICLE

Quality Indicators of Pediatric Asthma Care in the Emergency Department; a Systematic Review and Meta-Analysis

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Abstract: **Introduction:** The quality of healthcare for pediatric asthma patients in the emergency department (ED) is of growing importance. This systematic review aimed to identify and describe existing quality indicators (QIs) designed for use in the ED for pediatric asthma care. **Methods:** We systematically searched three main electronic databases in May 2023 for all English-language qualitative and quantitative publications that suggested or described at least one QI related to pediatric asthma care in the ED. Two reviewers independently selected the included studies and extracted data on study characteristics, all relevant QIs reported, and the rates of compliance with these indicators when available. The identified QIs were classified according to Donabedian healthcare quality framework and the Institute of Medicine (IOM) framework. When feasible, we aggregated the compliance rates for the QIs reported in observational studies using random effects models. The quality assessment of the included studies was performed using various Joanna Briggs Institute (JBI) tools. **Results:** We identified twenty studies, including six expert panels, 13 observational studies, and one trial. Together, these studies presented 129 QIs for use in EDs managing pediatric asthma. Among these QIs, 66 were pinpointed by expert panel studies, whereas 63 were derived from observational studies. Within the Donabedian framework, most indicators (86.8%) concentrated on the process of care. In contrast, within the Institute of Medicine (IOM) domain, the predominant focus was on indicators related to effectiveness and safety. Observational studies reported varying compliance rates for the 36 QIs identified in the expert studies. The included studies showed a wide range of bias risks, suggesting potential methodological variances. **Conclusion:** A significant number of QIs in pediatric asthma care have been proposed or documented in literature. Although most of these indicators prioritize the process of care, there is a conspicuous absence of outcome and structure indicators. This meta-analysis uncovered significant disparities in compliance to the identified QIs, highlighting the urgent necessity for targeted interventions to enhance pediatric asthma care in ED.

Keywords: Quality indicators, health care; Asthma; Pediatric emergency medicine; Emergency service, hospital

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1. Introduction

Current evidence indicates a global increase in both the prevalence and severity of asthma among children (1), affecting roughly 14% of children worldwide (2). This not only imposes a significant burden on families and society but also leads to increased demand and strain on hospitals, especially in emergency departments (EDs) that provide immediate medical care for most asthma attacks (1, 3). In the United States (US), asthma is among the top 10 reasons for children under the age of 18 visiting EDs (4), averaging over 10 ED visits per 100 individuals aged under 18 years (5). The escalating burden of asthma in children causes ED overcrowding, higher costs, limited resources, and variations in clinical practices (6). Consequently, the increasing demand for ED services necessitates ongoing enhancements in their organization, structure, and quality of care (7).

There is a growing consensus that medical care demonstrates variability in aspects such as quality, patient experiences, safety, costs, and outcomes (8). A study in US EDs highlighted variations in asthma care practices, identifying an increased use of radiographs, which leads to decreased ED efficiency, escalated care costs, and higher radiation exposure for children (9). Another study in the US underscored significant discrepancies between recommended therapies and the actual treatment provided to asthma patients in EDs. It revealed an underutilization of effective treatments, coupled

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with the overuse of unproven or ineffective therapies in managing pediatric asthma (10). Understanding this variation in performance is essential for maintaining and enhancing the quality of care in EDs.

The quality of care given to asthmatic patients in EDs is important for achieving improved patient outcomes (11). Quality indicators (QIs) and performance measures are crucial for enhancing healthcare in an ED setting, enabling healthcare providers and researchers to assess performance levels and spot areas needing improvement in clinical care (12). In the field of emergency medicine, various countries have established specific indicators to bolster improvements in patient care (13, 14). A few recent studies on ED care indicators for children have zeroed in on broad indicators such as time-orientation, staff training, follow-ups, and guideline usage (15). Both expert and observational studies have reported and assessed various QIs tailored to the ED care provided to pediatric patients with asthma (12, 13). However, these QIs demonstrate variations and specificity to certain healthcare systems. Ensuring high-quality healthcare for asthmatic patients in EDs is crucial for optimal treatment outcomes and reducing the burden of asthma-related complications.

To date, no comprehensive studies have been conducted to evaluate the existing QIs and measuring ED compliance with QIs for pediatric asthma care. The aim of this systematic review and meta-analysis is to identify the QIs for ED care for pediatric asthma patients, and to gauge the compliance of studied EDs with the QIs. This research is a significant step in thoroughly identifying and describing performance measures specifically designed for pediatric asthma care in the ED.

2. Methods

2.1. Study design and setting

This study constituted a systematic review and meta-analysis that included all prior studies that recommended and reported any QI for evaluating the performance of EDs in providing emergency medical care to pediatric patients with asthma. The systematic review complied with the structure and reporting guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist (16). The protocol of this project was registered with PROSPERO (Registration number: CRD 42023340048).

2.2. Search strategy (database details)

Three electronic databases, namely SCOPUS, CINAHL, and MEDLINE, were utilized for searching, using keywords and Medical Subject Heading (MeSH) terms related to the EDs, QIs, asthma, and pediatrics. There were no restrictions on the year of publication (Supplementary table1). Additionally, reference lists from the included studies were manually reviewed to identify any additional relevant studies.

2.3. Study selection

For inclusion, we focused on expert panel studies, clinical trials, and observational studies that specifically developed and/or reported at least one indicator pertinent to the ED care for pediatric asthma patients. Studies involving QIs for patients over 21 years were excluded.

Conference abstracts, commentaries, and letters to the editor were also excluded due to their limited information. After eliminating duplicates, the identified studies underwent two phases of independent screening against the inclusion criteria by two reviewers (IK and NH). The titles and abstracts were first examined, followed by an assessment of the full-text of articles for eligibility. Any disagreements or discrepancies among the reviewers were resolved by a third reviewer (AA).

2.4. Data collection and extraction

Two reviewers performed independent data extraction using a standardized data extraction form. Disagreements were reconciled through consensus. The primary data elements extracted encompassed the author's name, study design, study year and setting, age of the study population, pertinent QIs, and the assessment of compliance with these QIs, when reported.

2.5. Data synthesis and analysis

We categorized the identified QIs utilizing two established frameworks for healthcare quality: Donabedian's framework (17) and the Institute of Medicine (IOM) framework (18). Donabedian's framework divides the quality of care into three distinct areas: "structure," "process," and "outcome." The structure encompasses factors such as organizational structure, policies, and material resources. The process entails the steps involved in providing care to patients including the diagnostic process, treatment recommendations, and implementation of the treatment plan. The outcome centers on the effects of health care.

The IOM framework outlines care quality in six domains: effectiveness, timeliness, efficiency, safety, equity, and patient-centeredness. These domains offer a holistic approach for assessing care quality. Notably, a single QI may cover multiple domains and is assessed accordingly in this study.

For clarity, we further classified indicators by their function and modality of care. For instance, Donabedian's process indicators were organized by care function, including diagnosis, treatment, and follow-up. Diagnosis indicators examine processes for accurate diagnosis, such as history-taking, physical examination, and diagnostic tests. Treatment indicators included medication administration and treatment response monitoring. Follow-up indicators involved developing post-discharge plans, action plans, instructions, and arranging follow-up appointments.

2.6. Statistical analysis

Weighted percentages with 95% confidence interval (CI) were calculated for each QI reported in at least two studies, using Der Simonian and Laird random effects models (19). Heterogeneity across studies were evaluated by calculating the I2 statistic. All data were analyzed using Stata version 15 (Stata Corp.). A two-sided p-value of less than 0.05 was deemed statistically significant for all analyses.

2.7. Risk of bias assessment

We evaluated the quality of the included studies using four distinct assessment tools from the Joanna Briggs Institute (JBI), each tailored for a specific study design. These tools encompassed the JBI critical appraisal checklist for qualitative research, the updated JBI critical appraisal checklist for randomized controlled trials, and JBI critical appraisal checklist for cohort and analytical cross-sectional studies (20). We employed these checklists to evaluate qualitative and expert panel studies, randomized trials, and observational studies, respectively (20). Each study was independently appraised by two reviewers, with any disagreements being settled through consensus. According to JBI guidelines, studies were assigned grades reflecting their risk of bias, and these evaluations contributed to our synthesis and interpretation of the results.

3. Results

3.1. Search findings

Initially, our search strategy yielded a total of 977 titles. Following the removal of duplicates (n=208), 769 studies were screened based on their title and abstract. Out of these, 619 were excluded at this stage for being irrelevant. The remaining 150 studies were subjected to a thorough full-text assessment, culminating in 20 studies meeting the inclusion criteria and being incorporated into the review. Figure 1 illustrates the flow of article selection and exclusion throughout the review process.

3.2. Study characteristics

Table 1 summarizes the studies included in the review, detailing the first author, country, year, reference, study population (age), study design, and number of relevant QIs. Most studies were conducted in the United States (n=12), followed by Australia (n=4), Canada (n=3), and Spain (n=1). Among the included articles, six combined expert opinions, literature reviews, and field testing to develop the QIs, while one was a randomized clinical trial (RCT) (n=1), and 13 were observational studies (n=13). The study populations covered a wide range of age groups, encompassing diverse age ranges, from infants to young patients with an age range of 1–21 years. Notably, Significant variation was seen in the number of QIs per study, ranging from 1 to 40 QIs.

A total of 66 unique QIs were suggested and reported by expert studies (Table 2). Observational studies reported 36 QIs that matched those from the expert studies. However, 63 QIs were reported exclusively by the observational and RCT studies (Table 3).

3.3. Domains of existing QIs based on Donabedian and IOM frameworks

The 66 QIs proposed in expert studies primarily consisted of a process of care measures (n=63), covering areas like history (n=6), documentation and physical assessment (n=13), diagnostic procedures (n=4), medication (n=22), observing the response to treatment (n=10), and follow-up (n=8). Only two indicators focused on outcome measures, reflecting the ultimate impact of the provided care. Structure measures, indicated by one study, included elements like the percentage of EDs with clinical guidelines for pediatric asthma treatment.

In a similar vein, the 63 QIs identified exclusively in observational and RCT studies were mostly process of care metrics (n=49), including aspects such as history (n=8), documentation and physical assessment (n=13), diagnostic procedures (n=4), medication (n=17), and follow-up (n=7). Outcome indicators were represented by ten QIs, while structure-related indicators were represented by a total of four.

3.4. Meta-analysis of QIs for asthma care in ED

The compliance to most QIs was evaluated in one observational study, while a few commonly reported indicators were assessed by more than one observational study as detailed in Table 2. For instance, the indicators for chest radiography in asthma patients were evaluated in five studies. The pooled compliance for radiography usage was 31.0% (95% CI: 20.0-43.0, I2=100). The percentage of asthma patients treated with steroids in the ED was reviewed in six studies, indicating a combined compliance rate of 75.0% (95% CI: 72.0-79.0, I2=99.4). The rate of asthma patients receiving ipratropium in the ED, assessed in three studies, showed a unified compliance rate of 40.0% (95% CI: 0.0 - 83.0, I2=98.4). Additionally, the percentage of patients administered antibiotics in the ED, evaluated in three studies, displayed a collective compliance rate of 12.0% (95% CI: 0-35.0, I2=100). These results are visually depicted in Figure 2.

3.5. Risk of bias assessment

Our analysis using the JBI tool identified a range of bias risks in the included studies. Of the nine cross-sectional studies, three exhibited a high risk of bias, four presented an unclear risk, and two were considered to have a low risk. In the four cohort studies, two had a low risk of bias, while the other two had an unclear risk. Notably, none of the cohort studies were classified as having a high risk of bias. Regarding the six qualitative studies, three had an unclear risk of bias, one showed a low risk, and two were evaluated as having a high risk of bias. The single RCT included in our study demonstrated a low risk of bias. These assessments are visually detailed in Figure 3.

4. Discussion

In response to growing awareness of the quality of pediatric emergency medical care and an expanding evidence base, this review aimed to describe and evaluate the existing QIs for the performance of ED in treating pediatric asthma patients. A total of 129 QIs were proposed by both expert panel studies and observational studies. The majority of these QIs (86.8%), were concentrated on the process of care. A smaller proportion focused on care outcomes (9.3%) and structural aspects (3.9%), particularly in expert studies. According to the IOM framework, most identified QIs were centered on the domains of effectiveness and safety. Furthermore, compliance to most QIs exhibited significant variability across different studies and healthcare systems. This extensive range of QIs requires further assessment and consensus on aspects like terminology, compliance, validity, feasibility, and other crucial factors influencing their utilization.

Notably, several QIs were featured in multiple studies, highlighting their importance in daily healthcare practice and ED policies. Key examples include the use of chest radiographs, steroid administration, and the rate of antibiotic usage in the ED. Medical radiography, commonly used in the ED, is vital for diagnosis, providing prognostic insights, and guiding treatment decisions (10). Our meta-analysis supported previous studies indicating an overuse of radiography, with its utilization in pediatric asthma cases reaching 43.0% (12, 21). This overutilization not only prolongs pediatric patients' ED stays but also subjects them to unnecessary radiation, resulting in increased healthcare costs (10). It's heartening to observe a high compliance rate of 75.0% for treating asthma patients with steroids in the ED. However, the notable difference between compliance rates for treatment in the ED and discharging patients with a steroid prescription is alarming. This discrepancy highlights possible barriers or gaps in the transition from emergency care to outpatient or home-based care. Consequently, inadequate therapy during this transition phase could pose risks, such as increased revisits to the ED (22). Additionally, the compliance rates for antibiotics reached 35.0%, indicating potential overuse in asthma treatment in the ED. These results align with previous studies, which reported a 29% rate of antibiotic use for pediatric asthma patients in US EDs (10, 23). Overuse of antibiotics can lead to serious issues like the emergence of antibiotic-resistant strains and unnecessary healthcare costs, constituting a significant public health concern (10). Even though most indicators were evaluated in just one observational study, they remain critically important in assessing and managing respiratory diseases. An example of such indicators is the respiratory assessment score. Additionally, indicators not captured in observational studies, like the duration from arrival to systemic steroid administration for asthma patients, are essential in appraising the care provided to pediatric asthma patients in the ED.

In the healthcare quality domain, most QIs are focused on the care process, while a smaller number address care outcomes and structure, as outlined by the Donabedian framework (17). The high prevalence of process measures is attributable to their measurability, efficacy in evaluating healthcare quality, and adaptability by ED providers (24). However, there is a significant lack of comprehensive structural indicators in the ED environment. Further research is essential to investigate the interaction between structural elements and outcomes, as well as the connections between processes and outcomes, especially for pediatric asthma patients in the ED.

The identified QIs for asthma primarily align with the effectiveness and safety domains of the IOM framework (18). Yet, the efficiency and patient-centered domains are featured in less than half of these QIs. This emphasizes the need to improve resource utilization, eradicate disparities, and focus on patient-centered approaches in asthma care. Timeliness measures generally concentrate on indicators such as the time from arrival to the administration of systemic steroids in asthma exacerbation cases. It is important to highlight that the findings did not encompass any equity measures within the QIs from expert panel studies and included only a handful from observational studies.

Compliance with the identified indicators was evaluated using indicators from observational studies. The 36 QIs reported by observational studies matched with those reported by the expert studies. Our findings demonstrate different compliance levels with the QIs for asthma, underscoring the disparity in compliance to recommended practices among the indicators. The high I2 value signifies considerable heterogeneity among the studies. Potential sources of this heterogeneity may include differing sample sizes, variability in study methodologies and practice patterns. This stresses the need for caution when interpreting the pooled compliance rates and emphasizes the importance of further investigation into the factors contributing to the observed variations.

Our study identified diverse risks of bias across the included studies. In cross-sectional studies, the reliability and validity of exposure measurement, as well as strategies for handling confounding factors, appeared as the main sources of potential bias. For cohort studies, the articulation of strategies to mitigate confounding factors, together with considerations related to follow-up completeness and strategies for addressing incomplete follow-up, raised critical concerns. In qualitative and expert studies, the unclear congruence between philosophical perspectives and research methodology hinted at potential biases. Additionally, the failure to provide clear cultural or theoretical positioning posed risks in qualitative research. Future research must address these critical issues to reduce bias and enhance the reliability of findings in the ED treatment of pediatric asthma patients.

5. Limitations

Despite offering valuable insights, this review has several limitations that merit acknowledgment. Firstly, our decision to include only English-language articles might introduce publication bias. The exclusion of pertinent studies

published in other languages due to resource and funding limitations for translation could restrict the generalizability of our findings on a broader international scale. Furthermore, our review concentrated on studies from developed and high-income countries, where established quality improvement programs significantly influence service standardization. As a result, our findings may not be directly translatable to healthcare systems in developing or middle-income countries. It is also crucial to acknowledge that our meta-analysis relied on data from observational studies. Although these studies provide important real-world insights, they are inherently susceptible to biases and confounding factors, which could affect the accuracy and generalizability of our outcomes.

6. Conclusions

A significant number of QIs in pediatric asthma care have been proposed or documented in literature. Although most of these indicators prioritize the process of care, there is a conspicuous absence of outcome and structure indicators. The meta-analysis uncovers significant disparities in compliance to the identified QIs, highlighting the urgent necessity for targeted interventions to enhance pediatric asthma care in ED. The included studies demonstrated a wide range of bias risk levels, suggesting possible methodological discrepancies. Continued research and active collaboration among healthcare professionals are essential to advance pediatric emergency care and to elevate patient outcomes.

7. Declarations

7.1. Acknowledgments

None.

7.2. Conflict of interest

The authors declare no conflict of interest.

7.3. Funding

None.

7.4. Authors' contribution

Study design: IK, AA, MHF, NH. Data gathering: IK, AA, MHF, NH. Interpreting the findings: IK, AA, NH. Writing the first draft: IK, NH, AA, MHF. Critically revised the manuscript: All authors.

7.5. Using artificial intelligence chatbots

No conflict of interest.

7.6. Abbreviations

Emergency Department (ED). Quality Indicators (QIs). Institute of Medicine (IOM). randomized controlled trial (RCT). Joanna Briggs Institute (JBI). United States of America (USA). Risk of Bise (ROB). Short-acting beta-agonist (SABA). Medical Doctor (MD). partial pressure of carbon dioxide (PCO2). Pediatric Respiratory Assessment Measure (PRAM). Oxygen Saturation (SaO2). Respiratory Rate (RR). Heart Rate (HR). Arterial Partial Pressure of Carbon Dioxide (PCO2). Primary Care Physician (PCP). Intensive care unit (ICU).

7.7. Appendix

Research strategy Supplement S1.

References

1. Masoli M, Fabian D, Holt S, Beasley R. The global burden of asthma: executive summary of the GINA Dissemination Committee report. Allergy. 2004;59(5):469-78.
2. Homaira N, Wiles LK, Gardner C, Molloy CJ, Arnolda G, Ting HP, et al. Assessing appropriateness of paediatric asthma management: A population-based sample survey. Respirology. 2020;25(1):71-9.
3. Choi J, Lee GL. Common pediatric respiratory emergencies. Emergency Medicine Clinics. 2012;30(2):529-63.
4. System CotFoECitUSH. Emergency care for children: growing pains. National Academies Press Washington, DC; 2007.
5. Moorman JE, Akinbami LJ, Bailey CM, Zahran HS, King ME, Johnson CA, et al. National surveillance of asthma: United States, 2001-2010. Vital & health statistics Series 3, Analytical and epidemiological studies. 2012(35):1-58.
6. Campbell SM, Roland MO, Buetow SA. Defining quality of care. Social science & medicine. 2000;51(11):1611-25.
7. Lugo SE, Pavlicich V. Quality in triage: indicators in patients with respiratory disease. Pediatr Emerg Care. 2013;29(6):710-4.
8. America CoQoHCi. Crossing the quality chasm: a new health system for the 21st century: National Academies Press; 2001.
9. Knapp JF, Simon SD, Sharma V. Variation and trends in ED use of radiographs for asthma, bronchiolitis, and croup in children. Pediatrics. 2013;132(2):245-52.
10. Knapp JF, Simon SD, Sharma V. Quality of care for common pediatric respiratory illnesses in United States emergency departments: analysis of 2005 National Hospital Ambulatory Medical Care Survey Data. Pediatrics. 2008;122(6):1165-70.
11. Johnson LH, Chambers P, Dexheimer JW. Asthma-related emergency department use: current perspectives. Open Access Emerg Med. 2016;8:47-55.
12. Guttmann A, Razzaq A, Lindsay P, Zagorski B, Anderson GM. Development of measures of the quality of emergency department care for children using a structured panel process. Pediatrics. 2006;118(1):114-23.
13. Mangione-Smith R, Roth CP, Britto MT, Chen AY, McGalliard J, Boat TF, et al. Development and Testing of the P ediatric R espiratory I llness Me asurement S ystem (PRIMES) Quality Indicators. Hospital Pediatrics. 2017;7(3):125-33.
14. Schull MJ, Guttmann A, Leaver CA, Vermeulen M,

Hatcher CM, Rowe BH, et al. Prioritizing performance measurement for emergency department care: consensus on evidencebased quality of care indicators. Canadian Journal of Emergency Medicine. 2011;13(5):300-9.
15. Flores G, Lee M, Bauchner H, Kastner B. Pediatricians' attitudes, beliefs, and practices regarding clinical practice guidelines: a national survey. Pediatrics. 2000;105(3 Pt 1):496-501.
16. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 2010;8(5):336-41.
17. Donabedian A. The quality of care: how can it be assessed? JAMA. 1988;260(12):1743-8.
18. Institute of Medicine Committee on Quality of Health Care in A. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington (DC): National Academies Press (US) Copyright 2001 by the National Academy of Sciences. All rights reserved.; 2001.
19. DerSimonian R, Laird N. Meta-analysis in clinical trials. Controlled clinical trials. 1986;7(3):177-88.
20. studies TJBICAtWfa. CRITICAL APPRAISAL TOOLS: JBI; 2023 [Available from: https://jbi.global/critical-appraisal-tools.
21. Buckmaster A, Boon R. Reduce the rads: a quality assurance project on reducing unnecessary chest X-rays in children with asthma. J Paediatr Child Health. 2005;41(3):107-11.
22. Education NA, Program P, Lung, Institute) B. Expert panel report: guidelines for the diagnosis and management of asthma: update on selected topics, 2002: US Department of Health and Human Services, Public Health Service, National; 2003.
23. Doherty S, Jones P, Stevens H, Davis L, Ryan N, Treeve V. 'Evidence-based implementation' of paediatric asthma guidelines in a rural emergency department. J Paediatr Child Health. 2007;43(9):611-6.
24. Rubin HR, Pronovost P, Diette GB. The advantages and disadvantages of process-based measures of health care quality. Int J Qual Health Care. 2001;13(6):469-74.
25. Stang AS, Straus SE, Crotts J, Johnson DW, Guttmann A. Quality indicators for high acuity pediatric conditions. Pediatrics. 2013;132(4):752-62.
26. Schumacher DJ, Holmboe ES, Van Der Vleuten C, Busari JO, Carraccio C. Developing resident-sensitive quality measures: A model from pediatric emergency medicine. Academic Medicine. 2018;93(7):1071-8.
27. Schumacher DJ, Martini A, Holmboe E, Varadarajan K, Busari J, van der Vleuten C, et al. Developing resident-sensitive quality measures: Engaging stakeholders to inform next steps. Academic Pediatrics. 2019;19(2):177-85.
28. Bardach NS, Vittinghoff E, Asteria-Peñaloza R, Edwards JD, Yazdany J, Lee HC, et al. Measuring hospital quality using pediatric readmission and revisit rates. Pediatrics. 2013;132(3):429-36.
29. Sills MR, Ginde AA, Clark S, Camargo Jr CA. Multicenter analysis of quality indicators for children treated in the emergency department for asthma. Pediatrics. 2012;129(2):e325-e32.
30. Kocher KE, Arora R, Bassin BS, Benjamin LS, Bolton M, Dennis BJ, et al. Baseline performance of real-world clinical practice within a statewide emergency medicine quality network: the Michigan Emergency Department Improvement Collaborative (MEDIC). Annals of emergency medicine. 2020;75(2):192-205.
31. Knapp JF, Hall M, Sharma V. Benchmarks for the emergency department care of children with asthma, bronchiolitis, and croup. Pediatric emergency care. 2010;26(5):364-9.
32. Sills MR, Fairclough D, Ranade D, Kahn MG. Emergency department crowding is associated with decreased quality of care for children with acute asthma. Annals of emergency medicine. 2011;57(3):191-200. e7.
33. Montealegre F, Chardon D, Vargas W, Bayona M, Zavala D. Measuring asthma disparities in Hispanics: adherence to the national guidelines for asthma treatment in emergency departments in Puerto Rico. Annals of Allergy, Asthma & Immunology. 2004;93(5):472-7.
34. Schumacher DJ, Martini A, Holmboe E, Carraccio C, van der Vleuten C, Sobolewski B, et al. Initial Implementation of Resident-Sensitive Quality Measures in the Pediatric Emergency Department: A Wide Range of Performance. Acad Med. 2020;95(8):1248-55.
35. Dexheimer JW, Abramo TJ, Arnold DH, Johnson KB, Shyr Y, Ye F, et al. An asthma management system in a pediatric emergency department. Int J Med Inform. 2013;82(4):230-8.
36. Browne GJ, Giles H, Mccaskill ME, Fasher BJ, Lam LT. The benefits of using clinical pathways for managing acute paediatric illness in an emergency department. Journal of quality in clinical practice. 2001;21(3):50-5.
37. de Mingo Alemany MC, Campos Andreu A, Ferrer Lorente B, López Salgueiro R. Medical audit on children with asthma in an Emergency Department. Allergol Immunopathol (Madr). 2009;37(4):198-202.

Table 1: Characteristics of included studies

First author, Country, Year	Study Design	Age (years)	QIs (n)
Guttmann et al., Canada 2006 (12)	Expert panel, literature review	1–19	9
Mangione-Smith et al., USA 2017 (13)	Expert panel, literature review	2–18	32
Schull et al., Canada 2011 (14)	Expert panel, literature review	Not specified	4
Antonia et al., Canada 2013 (25)	7 Expert panel, systematic review	<19	16
Schumacher et al., USA 2018 (26)	Expert panel, literature review	Not specified	16
Schumacher et al., USA 2019 (27)	Expert panel, mixed methods	Not specified	20
Naomi et al., USA 2013.(28)	Retrospective	1-21	2
Marion et al., USA 2011 (29)	Prospective	2-17	7
Kocher et al., USA 2019 (30)	Retrospective	<18	1
Knapp et al., USA 2010 (31)	Retrospective	1-19	3
Sills et al., USA 2011 (32)	Retrospective	2-21	14
Montealegre et al., USA 2004 (33)	Retrospective	<17	14
Knapp et al., USA 2008 (10)	Retrospective	1-19	4
Schumacher et al., USA 2020 (34)	Prospective	<17	19
Dexheimer et al., USA 2013 (35)	Randomized clinical trial	2–18	8
Doherty et al., Australia 2007(23)	Prospective	1-15	7
HOMAIRA et al., Australia2020 (2)	Retrospective	<15	23
BROWNE et al., Australia 2001 (36)	Prospective	<15	3
A Buckmaster et al., Australia 2005 (21)	Prospective	1-15	1
Alemanya et al., Spain 2009 (37)	Retrospective	2-14	40

QIs: Quality indicators of pediatric asthma care in emergency department.

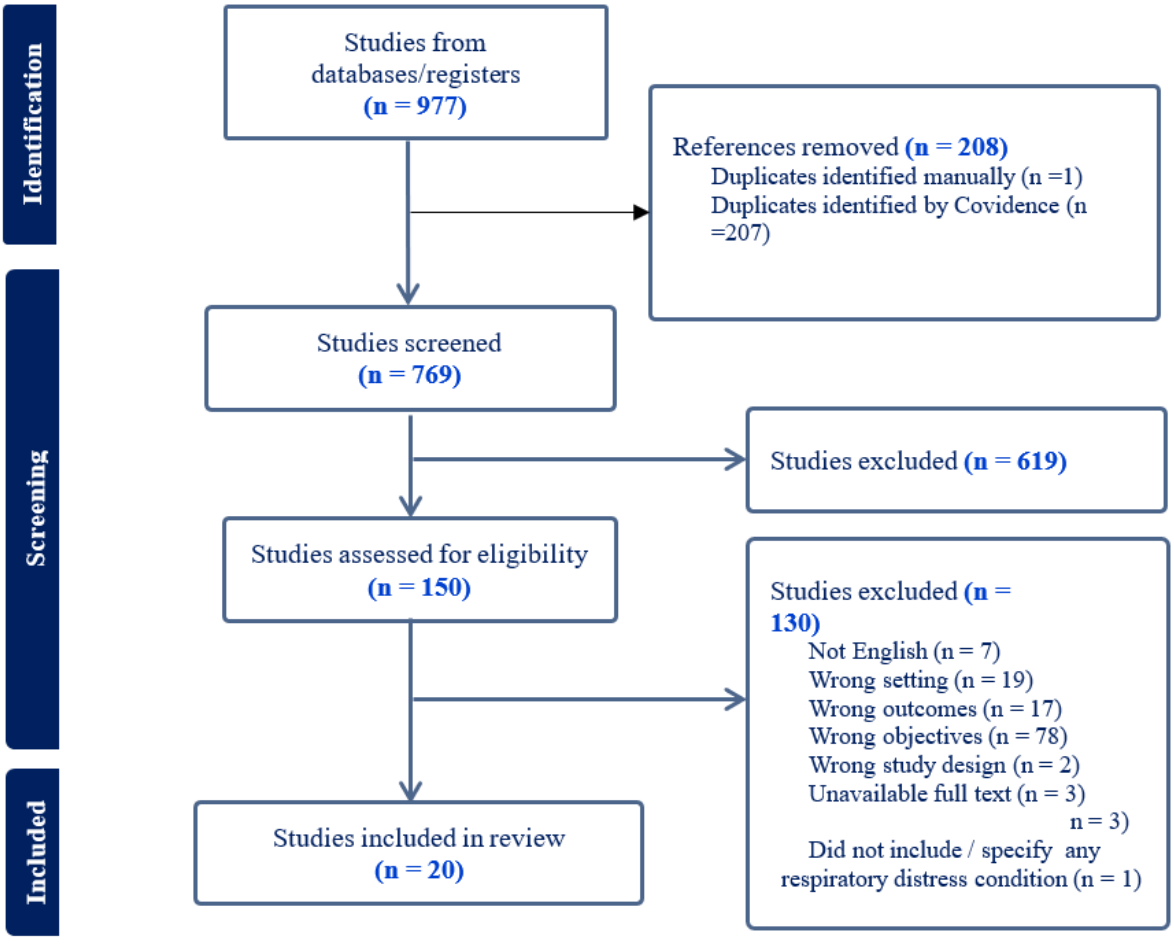

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram for the included studies.

Table 2: Quality indicators of pediatric asthma care in emergency department derived from expert panel studies: descriptions of measures, quality domains, and alignment of 36 indicators with observational studies

Donabedian		Quality indicators for asthma	IOM						Observational	Pooled % (95% CI)	I^2
Process			Effectiveness	Timeliness	Efficiency	Safety	Equity	Patient-Centeredness			
Diagnosis	History	Documentation of previous intubation or bilevel positive airway pressure for asthma (26, 27, 34).	√			√			1	26.4 (18.4-35.6)	
		All children presenting to the ED with an acute exacerbation of asthma should provide a history that includes triggers of exacerbations (13, 37).	√					√	1	32.0 (19.5-46.7)	
		All children presenting to the ED with an acute exacerbation of asthma should provide a history that includes current asthma (treatment) medications (13, 37).	√			√			1	24.0 (13.1-38.2)	
		All children presenting to the ED with an acute exacerbation of asthma should provide a history that includes hospitalizations in the past year for asthma (13, 33).	√						1	2.97 (2.40-3.63)	
		All children presenting to the ED with an acute exacerbation of asthma should provide a history that includes time of onset or duration of symptoms, and Short-acting beta-agonist (SABA) quantity used in the past month. Presence or absence of episodes of respiratory insufficiency due to asthma, or presence or absence of potentially complicating illnesses should also be included (13).	√	√		√			0	–	
		Flu status: During flu season (November to March), all children admitted to the ED for acute exacerbation of asthma should have their influenza vaccination status documented (13).	√	√		√			0	–	
	Physical Assessment	Time of first assessment: All children presenting to the ED with an acute exacerbation of asthma should have their initial assessment with 15 minutes of ED arrival (13).	√	√		√			0	–	
		% of admitted patients with an objective assessment of severity on initial presentation (25)	√			√			0	–	
		Level of alertness (13)	√		√					–	
		Hydration status (13)	√		√					–	
		Documentation of work of breathing (26, 34)	√			√		√	1	98.2 (93.6-99.8)	
		Documentation of aeration/air exchange (13, 26, 34)	√			√			1	94.5 (88.5-98.0)	
		Pulse oximetry (13, 37)	√			√			1	70.0 (55.4-82.1)	
		Respiratory Rate (RR) (13, 37)	√			√			1	44.0 (30.0-59.0)	
		Heart Rate (HR)(13, 37)	√			√			1	64.0 (49.2-77.0)	
		Use of accessory muscles, retractions (13, 33)	√			√			1	99.2 (98.8-99.5)	
		Presence or absence of wheezing (13, 26, 34)	√			√			1	98.2 (93.6-99.8)	
		% of patients with asthma who received respiratory assessment score (25, 32)	√			√			1	83.4 (80.7-85.9)	
		The acuity of the patient in documentation (27, 34)	√			√			1	99.1 (95.0-100.0)	
	Diagnosis procedures	% of patients with asthma who had an objective measurement of lung function during primary ED assessment (peak flow) (14, 37)	√						1	0 (0.0-7.1)	

Table 2: Quality indicators of pediatric asthma care in emergency department derived from expert panel studies: descriptions of measures, quality domains, and alignment of 36 indicators with observational studies (continue)

Donabedian		Quality indicators for asthma	IOM						Observational	Pooled % (95% CI)	I^2
Process			Effectiveness	Timeliness	Efficiency	Safety	Equity	Patient-Centeredness			
		% of patients with asthma who had an objective measurement of lung function during primary ED assessment (spirometry) (14, 23)	√						1	65.6 (46.8-81.4)	
		% of patients who receive a chest radiograph during the ED visit (10, 12, 30-32, 37)	√		√				5	31.0 (20.0-43.0)	100
		Partial pressure of carbon dioxide (PCO2): All children presenting to the ED with an acute exacerbation of asthma deemed to be severe should have their PCO2 measured within 30 minutes of making this assessment (13).	√						0	–	
Treatment	Medication	% of patients treated with antibiotics in the ED (10, 12, 23, 31)	√		√				3	12.0 (0-35.0)	100
		% of patients treated with steroids (10, 12, 14, 23, 25-27, 29, 31-34, 37)	√						6	75.0 (72.0-79.0)	99.4
		% of patients who received ipratropium bromide in ED (13, 23, 25, 27, 29, 37)	√						3	40.0 (0-83.0)	98.4
		% of EDs treated with b2-agonist in ED (25, 29, 32, 37)	√						3	99.0 (98.0-100)	84.9
		Correct medication dose was ordered for dexamethasone (26, 27, 34).	√						1	61.8 (52.1-70.9)	
		Correct medication dose was ordered for ipratropium (26, 27, 34).	√						1	46.4 (36.8-56.1)	
		Correct medication dose was ordered for albuterol (26, 27, 34).	√						1	53.6 (46.8-81.4)	
		Time from resident assigning him/herself to patient to steroid order (25, 27, 34)	√	√					1	40.0 (30.8-49.8)	
		Children in the ED experiencing moderate to severe asthma exacerbation should receive systemic steroids within 1 hour (13, 29, 32).	√	√					2	36.6 (4.7-68.5)	99.5
		Resident-assigned pediatric respiratory assessment measure (PRAM) matches resident-placed initial medication order (26, 34)	√						1	50 (40.3-59.7)	
		% of patients discharged home from the ED with a prescription/supply for steroids (10, 12-14, 25, 26, 29, 34, 37)	√						4	48.5 (11.1-86.0)	99.9
		Short-Acting Beta-Agonists (SABAs) prescription at discharge (13, 37).	√						1	89.9 (78.9-96.6)	
		Use of standardized dosing for discharge medication (dexamethasone) (26, 34)	√						1	51.8 (42.0-61.4)	
		Time from arrival to first inhaled b2-agonist treatment (13, 14, 25).	√	√					0	–	
		% of patients admitted to hospital with steroid administration in the ED (IV or oral) (12)	√					√	0	–	
		% of patients discharged from the hospital with a controlled Medication (12, 25)	√						0	–	
		Oxygen: All children experiencing an acute exacerbation of asthma in the ED and should receive oxygen (13).	√						0	–	
		Flu vaccination: During flu season (November to March), all children admitted to the ED for acute exacerbation of asthma that have not yet received an influenza vaccine and have no documented contraindications should be vaccinated prior to discharge or refusal by patient/parent should be documented (13).	√					√	0	–	

Table 2: Quality indicators of pediatric asthma care in emergency department derived from expert panel studies: descriptions of measures, quality domains, and alignment of 36 indicators with observational studies (continue)

Donabedian		Quality indicators for asthma	IOM						Observ-ational	Pooled % (95% CI)	I^2
Process			Effec-tive-ness	Timeli-ness	Effi-ciency	Safety	Equity	Patient-Cen-tered-ness			
		Sedatives: Children admitted to the ED with an acute exacerbation of asthma should not receive sedatives unless part of a rapid sequence intubation (13).	√					√	0	–	
		Appropriate medication dosing (26)	√					√	0	–	
		Time from arrival to systemic steroid administered (25)	√					√	0	–	
		Steroid ordered at the same time or before albuterol/ipratropium (13).	√					√	0	–	
	Observing	Severe symptoms post-SABA assessment: All children presenting to the ED with an acute exacerbation of asthma who are experiencing severe symptoms should have vital signs (RR, HR pulse oximetry) and lung sounds reassessed and recorded within 15 minutes of each SABA treatment (13).	√		√				0	–	
		Mild symptoms: Children evaluated in the ED for acute exacerbation of asthma with no more than mild symptoms at least 60 minutes after SABA treatment should be discharged (13).	√	√		√			0	–	
		Mild/moderate symptoms post-SABA assessment: All children presenting to the ED with an acute exacerbation of asthma who are experiencing mild or moderate symptoms should have vital signs (RR, HR pulse oximetry) and lung sounds reassessed and recorded within 15 minutes of receiving 3 back-to-back SABA treatments (13).	√	√		√			0	–	
		Moderate symptoms on reassessment and SABA: Children in the ED with moderate asthma exacerbation symptoms during their first reassessment after 3 back-to-back SABA treatments in the ED should be given additional inhaled SABA every 60 minutes for the next 2 hours (13).	√	√					0	–	
		Severe symptoms on reassessment and SABA: Children in the ED with severe asthma exacerbation symptoms during their first reassessment after 3 back-to-back SABA treatments in the ED should be given hourly or continuous nebulized SABA x3 and then every hour until improvement of symptoms (13).	√	√					0	–	
		Time from arrival to expert consult for patients not improving after conventional treatment (25)	√	√					0	–	
		% of patients not improving who receive at least 1 second-line therapy (25)	√	√					0	–	
		Need for hospitalization - the first hour of treatment: All children admitted to the ED for acute exacerbation of asthma and who have continuing severe symptoms or an arterial partial pressure of carbon dioxide (PCO2) mmHg in patients with moderate symptoms should be hospitalized (13).	√	√					0	–	
		Documentation of response to intervention (26, 27, 34, 37)	√	√					2	78.4 (64.3-92.5)	100

Table 2: Quality indicators of pediatric asthma care in emergency department derived from expert panel studies: descriptions of measures, quality domains, and alignment of 36 indicators with observational studies (continue)

Donabedian		Quality indicators for asthma	IOM						Observational	Pooled % (95% CI)	I^2
Process			Effectiveness	Timeliness	Efficiency	Safety	Equity	Patient-Centeredness			
	Instruction and planning	Documentation of disposition decision (26, 27, 34)	√	√					1	0.91 (0.83-0.95)	
		Documentation of worsening respiratory symptoms as a reason to return in written discharge instructions (27, 34)	√	√					1	26.4 (18.4-35.6)	
		% of patients discharged from the hospital from the ED with a written action plan (12, 13, 25)	√			√		√	0	–	
		% of patients discharged with follow-up instructions (12)	√			√		√	0	–	
		% of discharged patients referred to an asthma education program (25)	√			√		√	0	–	
		Stated who to follow up with and included contact information in discharge papers (27, 34).	√			√		√	1	48.2 (83.7-96.6)	
		Follow-up: All children admitted to the ED for acute exacerbation of asthma and discharged home should have parental instruction to contact the child's PCP (Primary Care Physician) or an asthma specialist within 72 hours of discharge or a written referral if they lack a PCP or asthma specialist (13).	√			√		√		–	
		Documentation of needing albuterol more often than every 4 hours as a reason to return in written discharge instructions (27, 34)	√	√					1	21.8 (14.5-30.7)	
		Documentation of home dexamethasone instructions in written discharge instructions (26, 27, 34)	√	√					1	40.0 (30.8-49.8)	
Outcome		Unplanned return visit between 24 and 72 hours for same/related asthma exacerbation (12, 14, 25, 32, 36)	√			√		√	1	3.6 (2.3-5.4)	
		Unplanned return visit to any ED within 24 hour of index visit for same/related asthma exacerbation (12, 14)	√			√		√	0	–	
Structure		% of EDs with clinical guidelines for the treatment of asthma in children (25)	√			√		√	0	–	

ED: emergency department; EMR: electronic medical record; HER: electronic health record; ECG: electrocardiogram; AI: artificial intelligence; ML: machine learning; STEMI: ST-segment elevation myocardial infarction.

Table 3: Quality indicators of Asthma care in emergency department from observational and randomized clinical trial studies only; measure descriptions and quality domains

Donabedian		Quality indicators for asthma	IOM						Pooled percentage (95% CI)	I^2
Process			Effectiveness	Timeliness	Efficiency	Safety	Equity	Patient-Centeredness		
Diagnosis	History	History of asthma attack (33)	√						74.9 (73.3-76.4)	
		Nocturnal symptoms before ED visit (33)	√					√	5.68 (4.89-6.55)	
		Previous duration of the current crisis (37)	√						24.0 (13.1-38.2)	
		Crisis diagnosis (37)	√						86.0 (73.3 - 94.2)	
		Etiological diagnosis of asthma (37)	√						28.0 (16.2 - 42.5)	
		Usual treatment (37)	√						23.9 (2,39-38.1)	
		B-Agonist use at home (29)			√				8.55 (7.59 - 9.60)	
	Physical Assessment	Sociodemographic data (37)					√		100 (92.8 - 100)	
		Diagnostic impression (37)	√						100 (92.8-100)	
		Children who presented with an acute exacerbation of asthma and their work of breathing assessed (2).	√						98.1 (93.5-99.7)	
		Degree of severity (37)	√		√				23.9 (13.0-38.1)	
		Documentation of severity (23)	√		√				89.7 (79.9-95.7)	
		Cardiac auscultation (37)	√						100 (92.8-100)	
		Blood pressure (37)	√						0 (0- 7.11)	
		Temperature (37)	√						100 (92.8-100)	
		Time-asthma-score <1 hour (32)	√	√					45.0 (41.6-48.5)	
		At least 3 descriptive words were used in respiratory exam documentation (34)	√						99.0 (95.0-99.9)	
		Resident documents own Pediatric Respiratory Assessment Measure (PRAM) score (34)	√						59.0 (49.3-68.3)	
		Children who presented with an acute asthma and their consciousness level documented (2).	√			√			Not reported	
		Weight (37)	√						100 (92.8-100)	
	Diagnosis procedures	Measurement of Pulmonary Function Tests (PFTs) (23)	√						12.0 (10.9-13.2)	
		Rapid Streptococcus Test (37)	√			√			4 (0.48-13.7)	
		Laboratory Blood Gases (37)	√			√			4 (0.48-13.7)	
		Laboratory Blood Tests (37)	√			√			2 (0.05-10.6)	

Table 3: Quality indicators of Asthma care in emergency department from observational and randomized clinical trial studies only; measure descriptions and quality domains (continue)

Donabedian		Quality indicators for asthma	IOM						Pooled percentage (95% CI)	I^2
Process			Effectiveness	Timeliness	Efficiency	Safety	Equity	Patient-Centeredness		
Treatment	Medication	Nebulized - agonist treatment every 30 min (33)		√					74.1 (72.5-75.6)	
		Children aged ≥2 years with life-threatening asthma or an Oxygen saturation (SpO2) < 95% received supplemental oxygen (2).	√		√				Not reported	
		Children aged ≥2 years who presented with an acute exacerbation of asthma where there was no response to initial treatment were prescribed ipratropium bromide (250 g via inhalation) (2).			√	√			Not reported	
		Children aged >2 years who presented with an acute exacerbation of asthma and who received antibiotics had another condition requiring antibiotic therapy (2).	√			√			Not reported	
		Fluid (37)			√	√			0 (0-7.11)	
		Not treated with methylxanthines in ED (29)	√						99.8 (99.4-100)	
		Use of aminophylline (33)				√			11.6 (10.5-12.8)	
		Theophylline (37)				√			0 (0- 7.11)	
		Children aged 5–12 years with persistent poorly controlled asthma requiring the maximum dose of inhaled steroids were referred to a specialist (2).	√						Not reported	
		Children who presented with an acute exacerbation of asthma were not prescribed an oral 2 agonist (2).	√						Not reported	
		Beta2, ipratropium, and corticosteroids were adjusted to body weight (37).			√	√			100 (92.8 - 100)	
		Oral corticosteroids were adjusted to body weight (37).			√	√			92.0 (80.7-97.7)	
		Children presenting with a mild/moderate exacerbation of asthma were prescribed an inhaled 2 agonist via a spacer (23).		√					65.6 (46.8-81.4)	
		Children aged ≥2 years who presented with a severe exacerbation of asthma were prescribed an inhaled 2 agonist via an oxygen-driven nebulizer (2).	√		√				Not reported	
		Use of standardized dosing for discharge medication (dexamethasone) (34)	√		√				51.8 (42.0-61.4)	
		Ipratropium prescribed for home (37)	√		√				41.9 (28.1-56.7)	
		Treatment for home (37)	√		√				39.0 (37.3-40.8)	

Table 3: Quality indicators of Asthma care in emergency department from observational and randomized clinical trial studies only; measure descriptions and quality domains (continue)

Donabedian		Quality indicators for asthma	IOM						Pooled percentage (95% CI)	I^2
Process			Effectiveness	Timeliness	Efficiency	Safety	Equity	Patient-Centeredness		
Follow-up	Instruction and planning	Referral to a specialist (33)	√		√				3.48 (2.87-4.19)	
		Justification of admission (37)	√						2 (0.05-10.6)	
		Written short-term asthma management plans for discharged patients (23)	√	√				√	69.3 (54.5-81.7)	
		Time to disposition, median (35)	√						289 (184 375)	
		Asthma education charted (35)	√						0.91 (0.88-0.94)	
		Take-home asthma prescription was charted (%) (35).	√		√				91.8 (88.5-94.5)	
		Follow up appointments were scheduled (%) (33, 35).	√					√	59.2 (57.4-60.9)	
Outcome		The length of stay (hour) (36)	√					√	Not reported	
		30 day re-admission rate after discharge (28)	√					√	3.00 (2.83-3.17)	
		30 day re-visit after discharge (28)	√					√	6.30 (6.05-6.54)	
		Transfer to Intensive care unit (ICU) <12 hours after ED admission (32)		√		√			0.72 (0.08-2.61)	
		Discharged (%) (35)		√		√			62.8 (57.6-67.8)	
		Re-presentation after discharge (36)	√			√		√	3.9 (0.58-2.86)	
		Admissions to intensive care unit or intubations (33)		√	√	1.			0.25 (0.11-0.50)	
		Admission to hospital (%) (21, 35, 36)	√			2.			28.9 (16.7-41.0)	95.4
		Unnecessary chest radiography (21)			√	√			36.5 (29.8-43.6)	
		Left without being seen by a provider (32)				√			0.21 (0.02-0.77)	
		No insurance (32)	√						10.5 (8.66-12.7)	
		Public insurance (32)	√						57.2 (54.0-60.4)	
		Protocol in the chart (%) (35)					√		17.8 (14.0-22.2)	
		Has primary care provider						√	88.4 (86.2-90.4)	

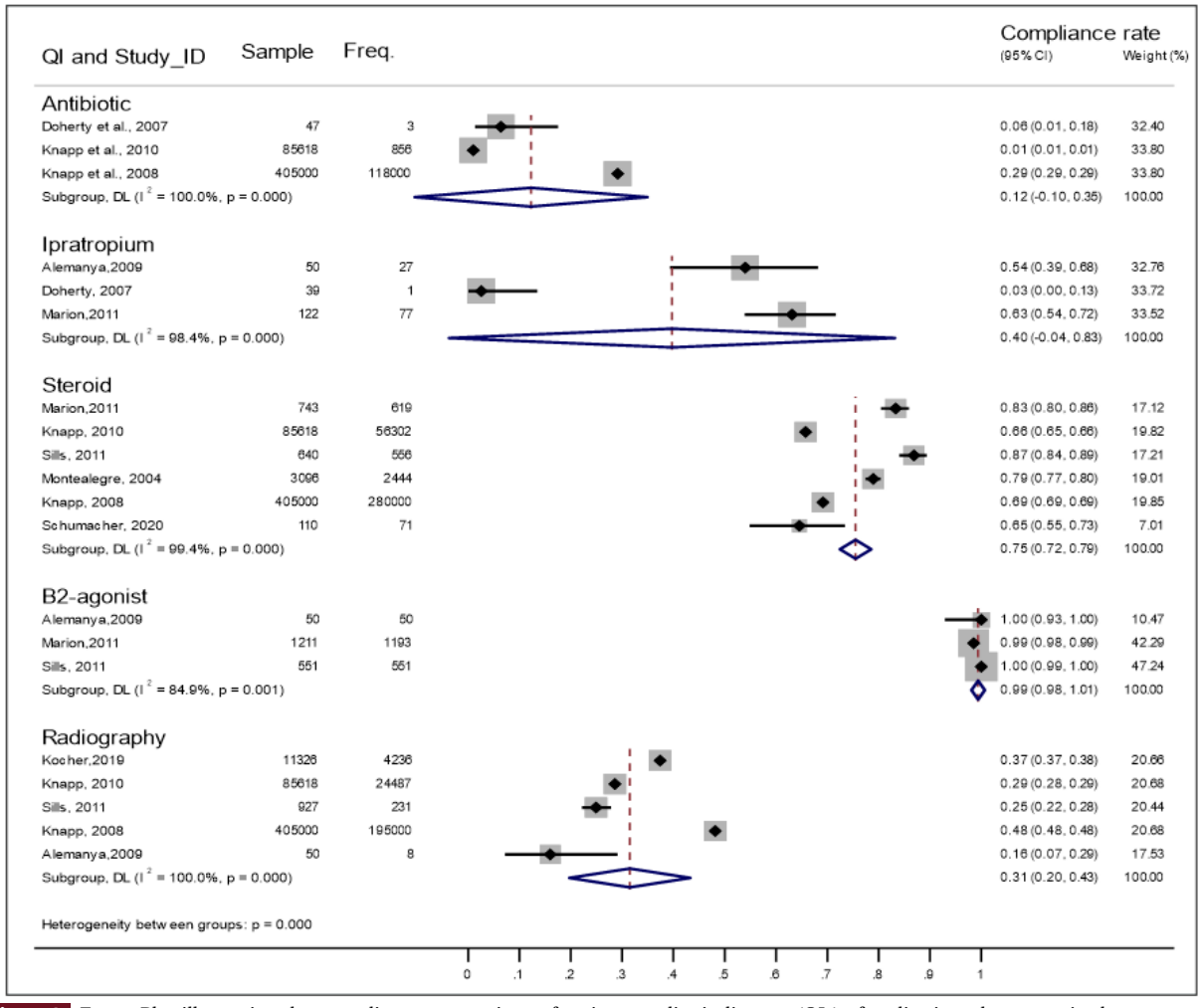

Figure 2: Forest Plot illustrating the compliance proportions of various quality indicators (QIs) of pediatric asthma care in the emergency department. CI: confidence interval.

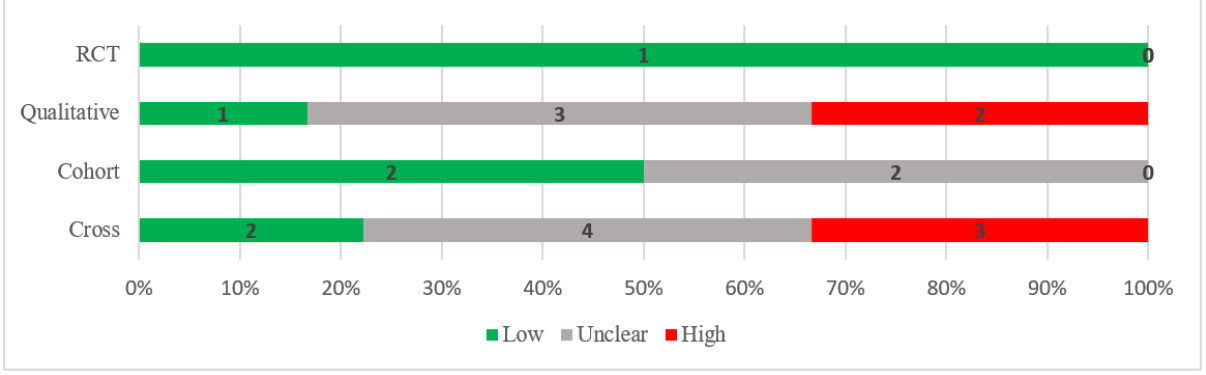

Figure 3: Risk of Bias assessment of included studies using Joanna Briggs Institute (JBI) tools. RCT: randomized clinical trials, Cross: cross-sectional.