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Characterizing Inequities in Pediatric Appendicitis Delayed Diagnosis and Perforation

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Objective We sought to characterize the impact of a child's sociodemographic characteristics on their odds of delayed diagnosis and perforation in pediatric appendicitis.

Study design We performed a single-center, retrospective cohort study of all pediatric appendicitis admissions between 2016 and 2021. Using a multivariable model, we evaluated for associations between delayed diagnosis and perforation and a child's sociodemographic characteristics, including their age, sex, race and ethnicity, insurance status, and their home census-tract Material Community Deprivation Index value.

Results The study included 3248 patients. The median age was 12.1 years (IQR 9.5-14.9 years). Most patients were male (60.3%), identified as non-Hispanic White (78.0%), and had private insurance (55.4%). The delayed diagnosis and perforation rates were 6.4% and 25.1%, respectively. Delayed diagnosis cases had a greater perforation rate (56% compared with 21.5%, $P < .001$). On adjusted analysis, older age decreased the odds (OR 0.91, CI 0.87-0.94) of delayed diagnosis, whereas female sex (OR 1.50, CI 1.13-2.00) and socioeconomic disadvantage (OR 1.56 for quartile 4 vs quartile 1, CI 1.00-2.43) increased the odds. Furthermore, older age (OR 0.91, CI 0.89-0.93) decreased the odds of perforation, whereas non-Hispanic Black (OR 1.72, CI 1.3-2.29) or Hispanic (OR 1.60, CI 1.24-2.08) compared with non-Hispanic White identification and socioeconomic disadvantage (OR 1.43 Q4 vs Q1, CI 1.12-1.83) increased the odds.

Conclusions Our reported delayed diagnosis rate is greater than recent literature, highlighting the need to consider visits that occur across different health care settings. We further identify sociodemographic factors, including socioeconomic status, that impact a child's risk of delayed diagnosis and perforation. *(J Pediatr 2024;11:200108).*

Appendectomy is the most common emergent pediatric abdominal procedure performed, with more than 75 000 pediatric admissions in the US for appendicitis annually.[1] Children who present with perforated appendicitis experience substantially greater morbidity than children without perforation. They experience greater rates of surgical-site and deep-space infections, require more procedures and imaging studies, and their prolonged hospitalizations can be disruptive to patients and families.[2-4]

There are significant inequities in the rates of perforated appendicitis among children. These inequities are influenced by the social determinants of health, defined as "the conditions in which people are born, grow, work, live, and age."[5] For example, there are greater rates of perforation for those with limited English-language proficiency,[6] those with public insurance or no insurance,[7-15] those from socioeconomically disadvantaged areas,[7,11,14,16] and those from rural areas.[7,17,18] In addition, studies have noted greater rates of perforation in Black and Hispanic children compared with White children.[6,10,14,19,20] Given that race is a social construct, with no biologically plausible link between self-identified race and perforation risk, this further suggests that racism in all its forms—whether implicit bias, explicit bias, or structural/systemic racism—may serve as a social determinant of health affecting appendicitis outcomes.

ED	Emergency department
EMR	Electronic medical record
MCDI	Material Community Deprivation Index
NH	Non-Hispanic
Q	Quartile
UC	Urgent care

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An initial presentation in which appendicitis is not diagnosed may result in a delay in definitive care and may be one potential driver of these inequities. Indeed, requiring multiple visits to make the diagnosis of appendicitis is associated with greater perforation rates.[7,21,22] However, the association of delayed diagnosis visits and specific sociodemographic characteristics of children with appendicitis has been rarely studied. Two studies have shown potentially greater rates of delayed diagnosis or misdiagnosis in Black compared with White children.[23,24] To our knowledge, no studies explicitly assess links between measures of socioeconomic status and delayed diagnosis visits.

Furthermore, delayed diagnosis for appendicitis has largely been defined based solely on emergency department (ED) presentations,[24-26] and often limited to the same ED.[21-23,27,28] As such, cases of delayed diagnosis in which children initially are seen in an outpatient clinic, in an urgent care (UC) setting, or even in another hospital's ED may not be captured. These cases may still be clinically relevant to delays in care and risk of perforation.

We performed a retrospective cohort study to address gaps in the current understanding regarding delayed diagnosis visits in pediatric appendicitis and to more fully characterize inequities in perforation rates. Understanding the drivers of these inequities is a first crucial step to closing equity gaps. We sought to first characterize cases of delayed diagnosis using a definition that captures any previous potentially related health care visit and then to evaluate for potential associations between delayed diagnosis and the sociodemographic characteristics of children with appendicitis.

Methods

We conducted a retrospective electronic medical record (EMR) review of all patients admitted to our quaternary care children's hospital between 2016 and 2021 with a diagnosis of appendicitis as defined by an *International Classification of Diseases*, *Tenth Revision*, *Clinical Modification* code of K35, K36, or K37.[19,23] The population was further limited to patients 18 years of age or younger at the time of admission and patients with appendicitis as the chief complaint and reason for admission (excluding incidental appendectomies). We also excluded patients who were subsequently readmitted after an initial hospitalization for appendicitis. We collected data on the patient's age at admission, sex, race, ethnicity, insurance type, address, date of admission, and date of discharge from the EMR. We performed further chart review to identify perforation status and potential cases of delayed diagnosis. This study was reviewed and approved by the hospital institutional review board.

Outcomes

The primary outcomes were delayed diagnosis visits and perforation. We defined delayed diagnosis cases as instances in which patients were sent home after presenting to a health care provider with an abdominal complaint (abdominal pain, nausea, vomiting, diarrhea) or fever, within the week before their appendicitis admission, or with a longer time frame but with continuous abdominal symptoms until admission for appendicitis. This is similar to definitions used in previous studies, except for a variety of time frames used to define delayed diagnosis (3 days to 30 days), and that other studies limited their visits to an ED and did not capture delayed diagnosis cases that occurred in an UC or in an outpatient clinic.[21-27] Instances in which patients were seen and referred to a higher level of care instead of being discharged home were not considered delayed diagnosis. We reviewed all cases of delayed diagnosis to confirm they met the definition and then to capture additional data points emerging from the "delayed diagnosis visit," defined as the initial visit when the patient was discharged without a diagnosis of appendicitis or further escalation in care. The additional data elements included the site of the index visit, the date of the visit, the presenting symptoms and physical examination findings, and the presumed diagnosis. We categorized the site of the index visit as occurring in an outpatient clinic, UC, or ED, and whether the visit occurred at our children's hospital and affiliated urgent cares, or at a community hospital or practice. We used the date of the index delayed diagnosis visit to calculate the time to diagnosis, defined as the number of calendar days between the index visit and the encounter during which the diagnosis of appendicitis was made. Lastly, if more than 2 visits were required to make the diagnosis, the first, or "index" visit, was the one characterized. Perforation status was based on operative reports, except in cases managed nonoperatively, where imaging results were used to determine perforation status. If perforation status was unclear from the operative report, then perforation status was based on pathology results.

Exposures

The primary exposures were the patients' race and ethnicity, primary language, insurance status, and their home census tract's Material Community Deprivation Index (MCDI). We considered age and sex as covariates. We characterized self-identified race and ethnicity as a single variable via the following groupings: non-Hispanic (NH) Black, Hispanic, NH White, and other (which included American Indian and Alaska Native, Asian, Middle Eastern, Native Hawaiian and Other Pacific Islander, other, patient refused, preferred category not available, and unknown). We defined primary language as English or non-English. We defined insurance status as private, public, or other. We geocoded and linked each child's address to a MCDI calculated at the census tract level. The index is created from 6 variables from US census data, including (1) percentage of households with income below the federal poverty level; (2) median household income; (3) percentage of the population ≥25 years with at least high school education; (4) percentage of the population without health insurance; (5) percentage of households receiving public assistance; and (6) percentage of housing units that are vacant. The index provides a broad reflection of a census tract or neighborhood's socioeconomic status. The index has a range of 0-1, with greater values indicating greater socioeconomic deprivation and has been previously reported and validated.[26,29-32]

Table I. Bivariate analyses for perforation and delayed diagnosis across sociodemographic groups

		Delayed diagnosis			Perforation		
Demographics	**Total % (No.)**	**No**	**Yes**	***P* value[*]**	**No**	**Yes**	***P* value[*]**
All patients	3248	93.6% (3041)	6.4% (207)	n/a	74.9% (2434)	25.1% (814)	n/a
Median age, y (IQR)	12.1 (9.5-14.9)	12.1 (9.5-14.9)	10.6 (6.9-14.1)	<.001	12.5 (9.7-15.1)	11.2 (8.0-13.8)	<.001
Sex				.006			.682
Male	60.3% (1959)	94.6% (1853)	5.4% (106)		75.2% (1473)	24.8% (486)	
Female	39.7% (1289)	92.2% (1188)	7.8% (101)		75.6% (961)	25.4% (328)	
Race and ethnicity				.695			<.001
NH White	78.0% (2533)	93.8% (2377)	6.2% (156)		77.6% (1965)	22.4% (568)	
Hispanic	10.2% (331)	92.7% (307)	7.3% (24)		63.7% (211)	36.3% (120)	
NH Black	8.0% (261)	92.3% (241)	7.7% (20)		65.5% (171)	34.5% (90)	
Other	3.8% (123)	94.3% (116)	5.7% (7)		69.7% (87)	29.3% (36)	
Primary language				.230			<.001
English	93.3% (3031)	93.8% (2842)	6.2% (189)		76.0% (2305)	24.0% (726)	
Non-English	6.7% (217)	91.7% (199)	8.3% (18)		59.4% (129)	40.6% (88)	
MCDI quartile (Q)[†,‡]				.022			
Q1	778	95.4% (742)	4.6% (36)		78.7% (623)	21.3% (189)	<.001
Q2	784	94.4% (740)	5.6% (44)		76.4% (599)	23.6% (185)	
Q3	787	92.1% (725)	7.9% (62)		74.5% (587)	25.5% (203)	
Q4	788	92.4% (728)	7.6% (60)		69.6% (548)	30.4% (237)	
Median MCDI (IQR)	0.28 (0.22-0.37)	0.27 (0.21-0.36)	0.30 (0.23-0.39)	.003	0.003	0.30 (0.23-0.39)	<.001
Insurance				.018			<.001
Private	55.4% (1799)	78.6% (1414)	21.4% (385)		78.6% (1414)	21.4% (385)	
Public	40.9% (1328)	69.8% (927)	30.2% (401)		69.8% (927)	30.2% (401)	
Other	3.7% (121)	76.9% (93)	23.1% (28)		76.9% (93)	23.1% (28)	

n/a, not available.

[*] χ^2 test was used for categorical variables and Kruskal-Wallis test for continuous variables.

[†] There was an inability to geocode 3.4% (n = 111) of cases because of inaccurate or missing addresses.

[‡] Greater MCDI values indicate greater socioeconomic deprivation.

Analysis

We used descriptive statistics for rates of perforation and delayed diagnosis overall and across each of the sociodemographic groups. We also used summary statistics to describe where delayed diagnosis visits occurred, the time to diagnosis, and the presumed initial diagnosis. We performed bivariate analyses using χ^2/Fisher exact tests and Kruskal-Wallis tests for categorical and continuous variables, respectively. We then developed multivariable logistic regression models to evaluate the role of each of the exposures and covariates in association with perforation (one model) and delayed diagnosis (a second model). In the multivariable models, we ultimately included age, sex, race and ethnicity, and MCDI. Primary language and insurance were not included in the final models for 2 reasons. First, both factors were associated with other included predictors and removing them reduced collinearity; primary language was associated with race and ethnicity and insurance status was associated with MCDI. Second, in the initial, expanded models that included all factors, both primary language and insurance status were not significant, with P values >.20. All analysis was carried out on SAS 9.4 statistical software (SAS Institute).

Results

A total of 3248 patients were included in the analysis. The median age was 12.1 years (IQR 9.5-14.9 years), and 60.3% were male. The majority (78%) were NH White, and the majority (93.3%) spoke English as their primary language. Of those in the non-English category, the majority (86%) reported Spanish as their primary language. The median deprivation index value was 0.28 (IQR 0.22-0.37), and just more than one-half of patients (55.4%) had private insurance.

Delayed Diagnosis and Perforation

The overall delayed diagnosis and perforation rates were 6.4% and 25.1%, respectively. Delayed diagnosis was associated with perforation; 56.0% of delayed diagnosis cases were ultimately perforated, whereas 21.5% of timely diagnosis cases were perforated ($P < .001$). On bivariate analysis, patient age, sex, deprivation index, and insurance status were all significantly associated with delayed diagnosis ($P < .05$, **Table I**). Similarly, patient age, race and ethnicity; primary language; deprivation index, and insurance status were all significantly associated with perforation ($P < .05$).

In our adjusted model for delayed diagnosis, we found that older children had lower odds of delayed diagnosis (OR 0.91, 95% CI 0.87-0.94), whereas female patients (OR 1.50, 95% CI 1.13-2.00), and children from greater deprivation neighborhoods (eg, for quartile [Q] 3 vs Q1, OR 1.62, 95% CI 1.06-2.49) all had greater odds of delayed diagnosis. Race and ethnicity and primary language were not associated with delayed diagnosis (**Table II**). In our adjusted model for perforation, older children had lower odds of perforation (OR 0.91, 95% CI 0.89-0.93), whereas NH Black (OR 1.72, 95% CI 1.30-2.29) or Hispanic children (1.60, 95% CI 1.24-2.08) compared with NH White children and children from greater deprivation neighborhoods (eg, for Q4 vs Q1, OR 1.43, 95% CI 1.12 – 1.83) all had increased odds of perforation. Sex was not associated with perforation rate (**Table II**).

Table II. Multivariable models for perforation and delayed diagnosis

	Delayed diagnosis		Perforation	
Model variables	**OR**	**95% CI**	**OR**	**95% CI**
Age (per year older)	0.91	0.87-0.94	0.91	0.89-0.93
Sex: female vs male	1.50	1.13-2.00	1.05	0.89-1.24
Race and ethnicity				
NH Black vs NH White	1.15	0.70-1.89	1.72	1.30-2.29
Hispanic vs NH White	0.89	0.55-1.43	1.60	1.24-2.08
Other vs NH White	1.02	0.46-2.24	1.46	0.96-2.23
MCDI quartile (Q)*				
Q2 vs Q1	1.18	0.75-1.86	1.17	0.91-1.49
Q3 vs Q1	1.62	1.06-2.49	1.23	0.96-1.57
Q4 vs Q1	1.56	1.00-2.43	1.43	1.12-1.83

*Greater values of MCDI indicate greater socioeconomic deprivation.

Characterizing Delayed Diagnosis Visits

The ED was the most common location for a delayed diagnosis visit (48.8%), followed by outpatient clinics (30.9%) and UCs (20.3%). The ultimate perforation rate after a delayed diagnosis visit in an ED, UC, or outpatient clinic was 51.5%, 71.4%, and 53.1%, respectively, with no statistically significant differences (P = .078, **Table III**). In our population, 29% of delayed diagnosis visits occurred in our facility (children's hospital) or in an affiliated ED or UC, with a greater perforation rate for delayed diagnosis visits occurring at our children's hospital compared with other locations (66.7% vs 51.7%, P = .049). There were also notable differences in which delayed diagnosis visits occurred across different sociodemographic groups (**Table IV**). For example, 37% of the index visits for NH White children occurred in an outpatient clinic compared with 20% and 4% for NH Black and Hispanic children, respectively. Furthermore, if only delayed diagnosis visits occurring in an ED were considered, then on bivariate analysis there was a statistically significant lower delayed diagnosis rate among White children compared with non-White children (2.86% vs 4.46%, P = .035).

There were significant differences in the perforation rates based on the length of time between the delayed diagnosis visit and the encounter in which the appendicitis diagnosis was confirmed (P = .008, **Table V**). The diagnosis of appendicitis was made after a total of 2 visits in 90% of cases (n = 187), after 3 visits in 8% of cases (n = 16), and after 4 or 5 visits in 2% of cases each (n = 2). The most common presumed initial diagnoses were gastroenteritis (47.8%), viral upper respiratory infection (11.1%), undifferentiated abdominal pain (9.2%), urinary tract infection (9.2%), and constipation (8.7%).

Table III. Where the delayed diagnosis visits occurred and associated perforation rate

Locations	Total	Perforation rate	P value*
Emergency department	48.8% (101)	51.5% (52)	.078
Urgent care	20.3% (42)	71.4% (30)	
Outpatient	30.9% (64)	53.1% (34)	
Children's hospital†	29.0% (60)	66.7% (40)	.049
Non-children's hospital	71.0% (147)	51.7% (76)	

*χ^2 test.
†Includes associated emergency department and urgent care sites.

Discussion

Our study is one of the largest retrospective studies of delayed diagnosis in pediatric appendicitis. We found greater than recently published rates of delayed diagnosis as well as a strong association between delayed diagnosis and perforation. Moreover, sociodemographic characteristics of children with appendicitis and their presentations were associated with delayed diagnosis and perforation in inequitable ways. Given the prevalence and impact of appendicitis, opportunities for more efficient and equitable diagnosis and management are critical to optimize outcomes for all children.

Our reported perforation rate was 25.1%, which was similar to pediatric rates reported in the literature.[7,11,17] Our reported delayed diagnosis rate of 6.4% is greater than recent studies, which reported rates between 2.6% and 4.8%.[22-24,28] Our operational definition of delayed diagnosis likely explains this difference. Although previous studies have focused on visits occurring solely in an ED, our definition includes cases in which the index delayed diagnosis visit occurred in a variety of settings, including outpatient clinics, UCs, and other EDs. This broad view of delayed diagnosis—which includes understanding encounters that occur within and across phases of care and health systems—is critical for understanding how delayed diagnosis contributes to perforation risk and inequities in perforation for at least 3 broad reasons.

First, our comprehensive study may reflect a more accurate assessment of the true magnitude or clinical impact of delayed diagnosis. Indeed, our results highlight that delayed diagnosis may be more prevalent than previously thought, especially as our results may be an underestimation of the prevalence, given the retrospective nature of the study.

Second, despite occurring in a lower-acuity setting, we observed similar perforation rates (P = .078) for delayed diagnosis visits that occurred in an UC or outpatient clinic compared with an ED, highlighting that visits in these settings are clinically important and worth considering. Furthermore, we may have been underpowered to detect a true difference, with a greater perforation rate for delayed diagnosis visits in an UC setting compared with an ED setting (71.4% vs 51.5%). If the findings do represent a true difference, confounding by age may explain the results as delayed diagnosis cases in an UC occurred in younger patients. Alternatively, the findings could reflect differences in delayed diagnosis rates or types of delayed diagnosis cases in an UC compared with ED setting, which would warrant further investigation.

Lastly, this type of comprehensive assessment is essential in order to avoid possible selection bias when evaluating whether differences in delayed diagnosis across sociodemographic groups might contribute to existing inequities in perforation rates. In our study, although we are

Table IV. Where delayed diagnosis visits occurred across sociodemographic groups

Demographics	Total	Children's hospital*	Non-children's hospital	*P* value	ED	UC	Outpatient	*P* value
Total	207	29% (60)	71% (147)		48.8% (101)	20.3% (42)	30.9% (64)	n/a
Median age (IQR)	10.6 (6.9-14.1)	9.3 (6.2-13.0)	11.1 (7.7-14.9)	.009	12.1 (6.9-14.8)	8.5 (5.5-10.6)	11.5 (9.2-14.3)	.004
Race and ethnicity				<.001				.009
NH White	156	19.9% (31)	80.1% (125)		44.9% (70)	18.0% (28)	37.2% (58)	
Hispanic	24	66.7% (16)	33.3% (8)		62.5% (15)	33.3% (8)	4.2% (1)	
NH Black	20	45% (9)	55% (11)		50% (10)	30% (6)	20% (4)	
Other	7	28.6% (2)	71.4% (5)		85.7% (6)	0%	14.3% (1)	
Primary language				.040				.022
English	189	27.0% (51)	73.0% (138)		46.0% (87)	20.7% (39)	33.3% (63)	
Non-English	18	50% (9)	50% (9)		77.8% (14)	16.7% (3)	5.6% (1)	
MCDI quartile†				.190				.081
Q1	41	19.5% (8)	80.5% (33)		41.5% (17)	12.2% (5)	46.3% (19)	
Q2	44	38.6% (17)	61.4% (27)		38.6% (17)	22.7% (10)	38.6% (17)	
Q3	63	25.4% (16)	74.6% (47)		54.0% (34)	22.2% (14)	23.8% (15)	
Q4	59	32.2% (19)	67.8% (40)		55.9% (33)	22.0% (13)	22.0% (13)	
Insurance				.215				.104
Private	96	22.9% (22)	77.1% (74)		46.9% (45)	14.6% (14)	38.5% (37)	
Public	104	34.6% (36)	65.4% (68)		51.9% (54)	24.0% (25)	24.0% (25)	
Other	7	28.6% (2)	71.4% (5)		28.6% (2)	42.9% (3)	28.6% (2)	

*These include visits to the children's hospital or an affiliated ED or UC.

†Greater MCDI values represent greater socioeconomic deprivation.

underpowered for the analysis, we did not find an association between race, or primary language, and delayed diagnosis. However, 2 previous studies found greater rates of delayed diagnosis or misdiagnosis for Black compared with White children.[23,24] These differences could be attributable to the types of cases included in the analyses. There are differences in where different sociodemographic groups may initially present, and therefore only evaluating certain settings could lead to a selection bias. For example, in our study, if we only considered cases that occurred in an ED, then on bivariate analysis there is a statistically significant lower rate of delayed diagnosis among White children compared with non-White children (2.89% vs 4.46%, $P = .035$). This is especially important to note, as there are new tools that can help identify cases of delayed diagnosis or misdiagnosis in pediatric appendicitis in administrative databases.[26,32] Although these tools are promising, given their ability to identify large numbers of misdiagnosis or delayed diagnosis cases for further study, one key limitation is that they currently only focus on the ED setting and thus need to be carefully applied to equity-related questions.

Table V. Time to diagnosis and perforation rate

Times to diagnosis	Total patients	Perforation rate	*P* value*
All visits	3248	25.1% (814)	n/a
All delayed diagnosis visits	207†	56.0% (116)	n/a
<1 d	12	25% (3)	.008
1 d	83	49.4% (41)	
2 d	46	56.5% (26)	
3-4 d	30	80% (24)	
5-7 d	21	52.4% (11)	
>7 d	13	76.9% (10)	

*χ^2 test.

†Missing data on time to diagnosis for 2 patients.

We found several associations between the sociodemographic characteristics of children with appendicitis and their odds of delayed diagnosis. Specifically, younger children and girls, compared with boys, both had greater odds of delayed diagnosis, highlighting the need for a greater degree of suspicion in these populations. Younger children may have difficulty clearly describing their pain or severity of their symptoms, contributing to difficulty making the diagnosis and greater odds of delayed diagnosis and greater perforation rate.[33] Possible explanations for greater delayed diagnosis rates in female patients include a broader differential for lower abdominal pain and/or possible biases in interpreting presentations and pursuing workup.

There may also be an association between measures of socioeconomic status and delayed diagnosis. Specifically, bivariate analyses revealed that both deprivation index and insurance status were associated with delayed diagnosis, and on adjusted analysis, children from neighborhoods with greater quartiles of deprivation had greater odds of delayed diagnosis. The association between socioeconomic disadvantage and odds of delayed diagnosis could be related to several factors, including practice variation in the initial evaluation and workup and available diagnostic resources. Furthermore, confounding from other delays in accessing care could contribute to greater perforation rates on initial evaluation, which may impact the odds of delayed diagnosis.

In addition, although delayed diagnosis is related to perforation risk, it remains only one of many potential drivers of inequities in perforation. Delayed diagnosis and perforation are clearly related; patients who experienced a delayed diagnosis also had more than double the perforation rate compared with those who experienced a timely diagnosis (56.0% vs 21.5%, $P < .001$). However, although delayed diagnosis and perforation had similar associations with specific sociodemographic characteristics of children with appendicitis (ie, age and socioeconomic deprivation), we noted several differences, including the association of delayed diagnosis with sex and the association of perforation with race and ethnicity. We also note that the differences in perforation rates (eg, an absolute difference of 13.9% between Hispanic children and NH-White children) exceed the overall rates of delayed diagnosis. Therefore, our findings indicate that initial delayed diagnosis or possible misdiagnosis is not the sole driver of inequities in perforation rates and highlights the need to identify other potential drivers of equity gaps in perforation rates among children.

Lastly, we noted an association between the time to diagnosis after an initial delayed diagnosis visit and perforation rate. In our population, those who were diagnosed with appendicitis on the same calendar day as their initial delayed diagnosis visit had a perforation rate of 25.0%, which was similar to the overall population perforation rate of 25.1%. In contrast, if the encounter during which they were definitively diagnosed occurred on the next calendar day, the perforation rate increased to 49.4%. By day 3, the perforation rate was 80%. Understanding the urgency and time relevance of diagnosis may help guide provider decisions regarding observation vs discharge with return precautions for patients with an unclear diagnosis. Specifically, our findings underscore the importance of explicit return precautions that direct patients to be re-evaluated within 12-24 hours for concerning symptoms, and account for individual families' access to timely care.

Limitations

Our study had several limitations. We relied on EMR review to determine cases of delayed diagnosis and hence likely did not capture cases of delayed diagnosis when providers did not document relevant historical information like previous visits. This also means that although our delayed diagnosis rate is the highest reported in recent literature, it is likely an underestimation, highlighting the need for prospective evaluation. We were also unable to evaluate for causation and fully assess the complicated relationship between delayed diagnosis and perforation as a result of the retrospective study design. Although this is the largest single-institution study in the literature, with more than 3400 patients, we are still underpowered to evaluate for associations between a range of sociodemographic characteristics of children with appendicitis and likelihood of delayed diagnosis. Furthermore, as a single-institution study with population demographics unique to our region, our findings may not generalize to other catchment areas and regions across the US. Lastly, race and ethnicity are social constructs with key limitations. Nevertheless, given the notable inequities in perforation rates across racial and ethnic groups, and the need to better characterize these inequities to begin addressing them, it is essential to include race and ethnicity in this study. Moreover, their inclusion is consistent with recommendations on reporting race and ethnicity in medical research.[34,35] This categorization is consistent with the reported literature.[7,23,24]

Conclusions

We report a delayed diagnosis rate of 6.4% in pediatric appendicitis, which is greater than recent literature and highlights the need to consider delayed diagnosis or potential misdiagnosis visits that occur in health care settings other than the ED. Our findings indicate that younger age, female sex, and greater socioeconomic disadvantage are important risk factors for delayed diagnosis. Given the limitations of a retrospective analysis, prospective evaluation of delayed diagnosis and associated risk factors is needed. Furthermore, delayed diagnosis or potential misdiagnosis is only one driver of the observed inequities in perforation; efforts to identify additional drivers of differential outcomes in perforation rates are essential to close equity gaps. ■

CRediT Authorship Contribution Statement

Stephen Trinidad: Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Raphael Parrado:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Amelia Gavulic:** Writing – review & editing, Investigation, Data curation. **Mindy Hoang:** Writing – review & editing, Investigation, Data curation. **Qing Duan:** Writing – review & editing, Validation, Software, Formal analysis. **Kevin M. Overmann:** Writing – review & editing, Validation, Supervision, Investigation. **Ndidi Unaka:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Andrew F. Beck:** Writing – review & editing, Supervision, Resources, Investigation, Funding acquisition, Conceptualization. **Meera Kotagal:** Writing – review & editing, Supervision, Resources, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

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