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Barriers and facilitators of CT scan reduction in the workup of pediatric appendicitis: A pediatric surgical quality collaborative qualitative study

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ABSTRACT

Introduction: Despite ongoing efforts to decrease ionizing radiation exposure from computed tomography (CT) use in pediatric appendicitis, high CT utilization rates are still observed across many hospitals. This study aims to identify factors influencing CT use and facilitators and barriers to quality improvement efforts.

Methods: The Pediatric Surgery Quality Collaborative is a voluntary consortium of 42 children's hospitals participating in the National Surgical Quality Improvement Project - Pediatric. Hospitals were compared based on CT utilization from January 1, 2019, to December 31, 2019. Semi-structured interviews were conducted with surgeons, radiologists, emergency medicine physicians, and clinical data abstractors from 7 hospitals with low CT use rates (high performers) and 6 hospitals with high CT use rates (low performers). A mixed deductive and inductive coding approach for analysis of the interview transcripts was used to develop a codebook based on the Theoretical Domains Framework and subsequently identify prominent barriers and facilitators to CT reduction.

Results: Thematic saturation was achieved after 13 interviews. We identified four factors that distinguish high-performing from low-performing hospitals: (1) consistent availability of resources such as ultrasound technicians, pediatric radiologists, and magnetic resonance imaging (MRI); (2) presence of and adherence to protocols guiding imaging modality decision making and imaging execution; (3) culture of inter-departmental collaboration; and (4) presence of a radiation reduction champion.

Conclusions: Significant barriers to reducing the use of CT in pediatric appendicitis exist. Our findings highlight that future quality improvement efforts should target resource availability, protocol adherence, collaborative culture, and radiation reduction champions.

Levels of Evidence: Level III

1. Introduction

Acute appendicitis is one of the most common indications for urgent surgery in children with an estimated 60 000 to 80 000 pediatric appendectomies performed annually in the United States [1,2]. Appendicitis is a significant source of healthcare cost and morbidity in children, and accurate and efficient diagnosis is a priority [3,4]. Computed Tomography (CT) scans are often obtained in

Abbreviations: ACS, American College of Surgeons; CT, Computed Tomography; MRI, Magnetic Resonance Imaging; NSQIP-Ped, National Surgical Quality Improvement Program Pediatric; PSQC, Pediatric Surgery Quality Collaborative; QIC, Quality improvement collaborative, SCRs, Surgical Clinical Reviewers; TDF, Theoretical Domains Framework; US, Ultrasound.

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adults given their ease of use and widespread availability [5]. However, in children, concerns surrounding the risks of ionizing radiation exposure during a CT scan are more pressing. Children are especially susceptible to the stochastic effects of ionizing radiation given the increased sensitivity of their dividing cells and longer life expectancy at the time of exposure [6]. Multiple national cohort studies have demonstrated a significant association between CT exposure and later hematologic and solid malignancy development [7–12]. Specific to appendicitis, a national cohort study showed a significantly higher rate of hematologic malignancies in patients exposed to CT, an association which was more pronounced in the pediatric population [13]. As a result, multiple professional societies including the American College of Radiologists and American College of Surgeons have recommended that CT scans be avoided as the first line approach in children with suspected appendicitis [14,15].

Accordingly, efforts have been made to implement diagnostic strategies for pediatric appendicitis that avoid CT scans. These strategies utilize diagnostic protocols where patients with a significant pre-test probability of appendicitis undergo ultrasound (US) as the first-line imaging modality. Magnetic resonance imaging (MRI) or CT can be used for inconclusive US results [16–18]. The implementation of such strategies has been shown to safely reduce CT use while being cost-effective [19–22]. However, significant CT utilization in the workup of pediatric appendicitis persists. Approximately 40% of children diagnosed with appendicitis receive a CT scan during their diagnosis with 27% receiving only a CT scan and no other imaging [23].

The Pediatric Surgery Quality Collaborative (PSQC) was formed in January 2020 and comprises 42 hospitals from across the United States. It collects and unblinds risk-adjusted outcomes data from participating hospitals utilizing the American College of Surgeons (ACS) National Surgical Quality Improvement Program Pediatric (NSQIP-Ped), with the goal of developing national collaborative relationships to deliver high quality, cost effective, and patient-centered pediatric surgical care. The collaborative wished to explore the reasons for continued CT usage in the workup of pediatric appendicitis among its participating institutions. Therefore, we aimed to conduct a qualitative study to determine the institutional barriers and facilitators of CT reduction to identify targets for quality improvement.

2. Methods

2.1. Identification of high and low performing institutions

The ACS NSQIP-Ped is a multi-center clinical registry that provides risk-adjusted patient and hospital-level surgical outcomes for patients <18 years of age. The program collects data on a range of pediatric operations from approximately 140 participating institutions using a well described sampling methodology [24,25]. Preoperative risk factors, intraoperative variables, and postoperative outcomes are abstracted by full time trained surgical clinical reviewers (SCRs) using standardized search criteria and a rigorous chart review process [26]. In 2013, NSQIP-Peds launched the Appendectomy Collaborative Pilot Project which extended the variables collected to include additional appendicitis specific measures such as pre- and postoperative imaging, parenteral nutrition, pathologic findings, detailed intraoperative findings, and perioperative resource utilization [27,28].

We used an aggregate collaborative NSQIP-Peds semiannual report detailing risk-adjusted hospital level outcome data from January 1, 2019, to December 31, 2019, for the 42 hospitals participating in the PSQC. Outlier status was determined by NSQIP-Peds. Hospitals were defined as outliers if the hospital's 95% adjusted binomial proportion confidence interval for a given metric did not include the aggregate rate of the entire cohort. Hospitals that were a low outlier in either rates of preoperative CT use or negative appendectomy rates were considered high performers. Hospitals that were a high outlier in either outcome were considered low performers. NSQIP-Peds surgeon champions at high and low performing institutions were approached to participate in the quality improvement project, have their data unblinded to the PSQC study team, and participate in a focus group. All institutions that were approached agreed to participate in interviews.

2.2. Semi structured focus groups and the theoretical domains framework

We conducted focus group interviews with both high and low performers to assess barriers and facilitators of CT reduction in the workup of appendicitis. The focus group approach allowed us to obtain viewpoints from multiple stakeholders in the CT reduction process, including representatives from pediatric surgery, pediatric radiology, pediatric emergency medicine, and SCRs.

We developed a semi structured interview guide using the Theoretical Domains Framework (TDF). The TDF is an integrative framework of 14 domains agreed upon by expert consensus to affect behavioral change [29]. Within each domain, we focused on evaluating themes that underpinned the reasoning for the current imaging modality of choice for appendicitis. For example, knowledge and beliefs surrounding the risks and benefits of CT and its alternatives, resource availability, protocolization of care, social and monetary influences, and the culture of quality improvement at the institution were themes that were thought to be pertinent. Low and high performers were asked specifically about barriers and facilitators to CT reduction. Questions were designed to be open-ended to allow for discussion and reciprocity between the interviewer and the interviewee, with suggested follow ups included to ensure key topics were covered. Each question was accompanied with suggested follow up questions should the interviewer need prompts to allow for further investigation. The interview guide was reviewed and approved by a multidisciplinary team of pediatric surgeons and qualitative researchers (Appendix).

Surgeon champions at participating institutions identified an appropriate time in which they and other key stakeholders (e.g., pediatric radiologists) could attend the focus group. Each focus group was conducted by a multidisciplinary team consisting of qualitative researchers, clinical surgeons, program staff, and clinical research fellows. No formal interview training was provided but attending surgeon interviewers were experts in the topic of appendicitis and most had previous quality improvement experience. Interviewers were limited to a select group which allowed for iterative improvements in interviewing skill over the course of the study. The focus groups were conducted between November 2020 and January 2021 over an internet conferencing application.

2.4. Coding and data analysis

Focus group interviews were recorded and transcribed by the study team, which consisted of four members, using a combined deductive and inductive approach. First, the coding team deductively developed a codebook of themes within each TDF domain suspected to be either a barrier or facilitator of CT reduction. An interviewees' reasoning behind their decision to use, or not use, CT was then coded as the most appropriate available theme. Team members individually coded the first focus group interview and reviewed and reconciled differences. The remaining transcripts were divided between two teams of two coders each. Differences between coders were reconciled during meetings with the entire coding team and any discrepancies were adjudicated by a third study team member. Potentially important themes that were not

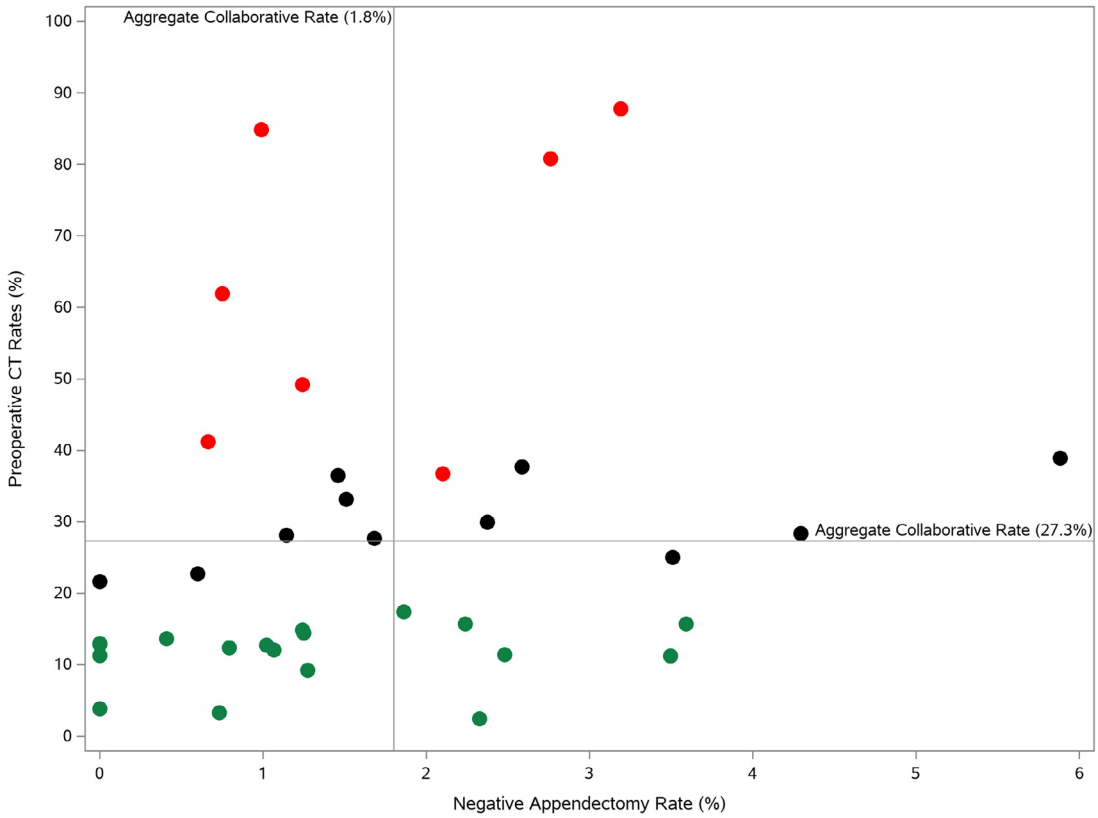

Fig. 1. American College of Surgeons National Surgical Quality Improvement Program Pediatric Semi-annual Report for Hospitals Participating in the Pediatric Surgical Quality Collaborative – Jan 1, 2019, to Dec 31, 2019. Red dots represent high outliers or low performers (high rates of CT use or high rate of negative appendectomies) while green dots represent low outliers or high performers (low rates of CT use or low rates of negative appendectomies). PSQC – Pediatric Surgical Quality Collaborative; CT – Computed Tomography; Appy – Appendectomy.

already included in the codebook were agreed upon by the coding team and added to the code book and subsequently applied to the remaining interviews (inductive approach). Once coding was complete, we identified the most relevant and common TDF domains that were barriers or facilitators to CT reduction.

The study team used MaxQDA 2020 (Berlin, Germany) to support data coding and analysis. This study was deemed non-human subjects research by our institutional review board. The purpose of the study was explained at the beginning of each focus group, and all participants in the focus groups gave verbal consent.

3. Results

The PSQC NSQIP-Peds semiannual report detailing risk-adjusted outcome data for the 42 participating hospitals identified 9 low performers and 17 high performers (Fig. 1).

We conducted 13 focus group interviews with 7 high performers and 6 low performers across 13 separate institutions within the PSQC before thematic saturation was achieved. We conducted 13 focus group interviews with 7 high performers and 6 low performers across 13 separate institutions within the PSQC before thematic saturation was achieved. Each focus group varied in size from 1 through 4 participants. In total, we had 28 participants including pediatric surgeons ($n = 13$), pediatric radiologists ($n = 5$), pediatric emergency medicine physicians ($n = 5$), and SCRs ($n = 5$). The findings included below are for themes that were frequently encountered and determined to be influential in the reduction of CT use for the workup of pediatric appendicitis. Table 1 provides illustrative quotes from both high and low performers for each theme, which is organized by TDF domain.

3.1. Availability of trusted alternatives to CT

One of the main factors found to influence CT reduction was the availability of effective alternatives to CT in the workup of appendicitis.

High performers felt they could often rely upon high quality US as their imaging modality of choice as it was available 24 h a day and 7 days a week. It was common in high performer focus groups for the pediatric surgeons to praise the skill and efficiency of their US technicians, who were often trained specifically in pediatric US. Similarly, high performers often cited the consistent availability of dedicated pediatric radiologists. Conversely, low performers reported that US availability was often limited in the evening hours or on weekends. They noted that non-diagnostic US studies at their institution were relatively common, citing the lack of dedicated pediatric US technician training as a potential cause. Similarly, while low performing institutions did have pediatric radiologists, their availability for imaging interpretation was intermittent.

Few high performing sites noted that MRI was critical to CT reduction. However, 3 sites noted that use of MRI following inconclusive US results represented an area for further improvement and were actively working to improve availability and develop rapid performance protocols. One site had increased their MRI capability to enable its use as a first-line imaging modality. For low performing centers, MRI usage in appendicitis was rare primarily due to limited availability of MRI machines.

3.2. Protocols for appendicitis workup

Protocoled diagnostic pathways for pediatric appendicitis, and adherence to these protocols was identified as a key factor. High

Table 1
Theoretical Domains Framework Domains, Themes, and Illustrative Quotes for Barriers and Facilitators of Computed Tomography Scan Reduction in Suspected Pediatric Appendicitis.

Domain	Theme	Performance	Quote
Environment	Pediatric Radiologist Availability	High	"…our US techs are very good. We have a few very experienced and are technically facile… the other [thing] is… it's only pediatric radiologists who are interpreting our US" [Surgeon]
		Low	"… the pediatric radiologists that we have are, you know, a Monday through Friday. Sort of 9 to 5 group…they'll come in, you know, on the weekend or in the middle of the night for some special procedure but if it's a read by the resident or a tech or adult radiologist, the quality may be not as good." [Surgeon]
	US availability	High	"We have 24/7 US in house tech support at the main hospital … that kind of changed our workflow considerably So we have the consistency and availability to perform an US on and off hours…" [Surgeon]
		Low	"So, the other the other aspect is, we don't have 24/7 US, so we only have US till about 6 P M. and so then you have the conundrum…" [Surgeon]
	MRI Availability	High	"…3 and a half years so we're getting a lot of CTs so we did this project and…They loved it at our hospital…then the radiologist [upon hearing about it said], hey, why don't we push this envelope a little further and you start to use MRI for non-diagnostic cases. So, they were the ones that wanted to lead this QI project, What's unique about our institutions [is] that we actually have 24, 7 MRIs, the machine's always on." [Surgeon]
		Low	"We have a few MRI scanners, but we have a robust neurosurgery practice…who are running 4 ORs at all times, so the MRIs you have to push hard to get in…so definitely not MRI 24/7 availability for children with suspected appendicitis. It's really hard. You have to pull out 1 of the tokens out of your back pocket"[Surgeon]
	QI Infrastructure	High	"We have a whole QI department actually… We have clinical quality and then more recently they established an Excellence department which is more process focused…in our clinical quality department, we have nurses pretty much exclusively that helped support" [Surgeon]
		Low	"…quality department is myself and my director who's actually leaving, so there's going to be some restructuring there and I'm not sure how that's going to look." [Surgical Clinical Reviewer]
Skills	US Technician Skill	High	"They're [US technicians] there 24/7, but more importantly, they're phenomenal and because there are so good, it [has] totally biased the way that we have created an algorithm or a flowchart because you know, a [lab result] isn't coming back fast enough and we're already getting fairly definitive data before that" [Surgeon]
		Low	"Diagnostic imaging is not great. We get a lot of non-diagnostic ultrasounds unfortunately" [Surgeon]
Memory and Decision Points	Protocol adherence	High	"We adopted a guideline for evaluation that included the pediatric appendicitis score and used that to help us guide whether imaging was necessary based on likelihood of appendicitis." [Surgeon]
		Low	"At one point about eight years ago developed a protocol that was supposed to … decide whether imaging was needed or not. However, with turnover in our ER staff, they pretty much have ignored that and go straight to imaging almost right off the bat." [Surgeon]
	US protocol technique	High	"We [Surgery and US techs] agreed on a standardized template…they're following that same template in terms of identifying imaging criteria, which would support a diagnosis so, by standardizing one technique [and] standardizing the reporting of appendicitis, that's what kind of got us to be able to turn around and give something more consistent" [Surgeon]
		Low	"There is a worksheet as they do the appropriate steps but I don't know if they are instructed to look for a specific period of time or go in a specific order…" [Surgeon]
Social or Professional Identity	Champion	High	"It was him [CT reduction champion] who got it going …. we used to do an appendix ultrasound on every abdomen ultrasound [because] the technologist needed the practice"[Surgeon]
		Low	"one of our senior partners here was interested in it and he literally gave up on the project because It was just going nowhere and he spent a huge amount of his own time…and it just went nowhere…unless it's a priority up high it just doesn't get a lot of weight." [Surgeon]
	MDT Involvement	High	"So, the CT rate, was upwards of 30% initially. This was about 2 years ago and because of that, we initiated this protocol, and we actually got buy in from everybody, including surgeons, and actually radiology, they were on board." [Emergency Medicine physician]
		Low	"We [Pediatric Surgery] discuss with them [Radiology] that they're [US] non diagnostic, but there's nothing really, I can do about that. They hire their own techs… they're not an academic radiology group and so I can only have so much effect over their division…" [Surgeon]
Intentions or Goals	Buy in	High	"So, I think having someone in radiology who's willing to be the champion is critical. Because again, like I said, you're dead in the water, if the radiologists aren't buying [in]…" [Surgeon]
		Low	"I think some of it has to do with current leadership and hopefully that leadership will change at some point in the future and then it might be a good avenue to change [practice] … I'm not sure my beating my head against the wall too many times is worth it for me right now." [Surgeon]
Social Influences	QI Culture	High	"…It's a very collaborative Children's hospital…we meet together on different tasks, I sit with the antibiotic stewardship and with the clinical effectiveness [team]. And when we were working on appendicitis, it was just so easy to get into a room with [the radiologist] and other stakeholders to talk through this [and] continue to work through it." [Surgeon]
		Low	"We don't have any dedicated administrative and academic time for quality improvement" [Surgeon]

Ultrasound (US); Magnetic Resonance Imaging (MRI); Quality Improvement (QI); Multidisciplinary Team (MDT).

performing centers reported having well defined protocols that categorized patients by risk of appendicitis and offered clear guidance regarding imaging indications, imaging decision makers, preferred imaging modalities, and when care should be escalated (e.g., surgical consultation). Practitioners endorsed that adherence to these protocols was high, and that there were multiple layers of reinforcement (e.g., monitoring by leadership or consistency of service providers). While some low performing centers reported appendicitis workup protocols, there were often concerns regarding adherence, with resultant variations in the decision-making process. Both high and low performing centers brought up the issue of staff turnover and its effect of protocol adherence. Centers relying on large rotating cohorts of ED practitioners or surgical trainees for coverage found it difficult to successfully implement protocolized care.

High performing centers consistently reported protocols for the performance of US, often with contingencies for an interval attempt should the first attempt be inconclusive (e.g., bladder filling to improve diagnostic yield). Similarly, high performing centers noted that US images were interpreted using a standardized protocol.

3.3. Radiation reduction champion and multidisciplinary involvement

The presence of a radiation reduction champion was a common factor that interviewees reported as integral in CT reduction efforts. High performers could often point to a single person that led the radiation reduction effort, typically a radiologist. This individual often had the support of their colleagues and the institution. They had the ability to dedicate significant effort and could rely on protected time to advance their quality improvement initiative. Although one champion led the initiative, their effort was usually supplemented with buy-in and involvement across surgery, radiology, and emergency medicine. Many high performers discussed previous successful inter-departmental quality improvement initiatives and had a regular cadence of multidisciplinary meetings to discuss progress of priority initiatives.

Low performers often expressed prior attempts by individuals to lead CT reduction quality improvement, but they felt that the time and effort invested was tempered by lackluster collaborative involvement and buy-in from institutional leadership. They also spoke about the more siloed nature of the departments at their hospitals and most did not have a history of inter-departmental collaboration.

3.4. Quality improvement infrastructure and institutional culture

High performing centers endorsed that they could rely on mature local infrastructure to facilitate quality improvement. They noted regular quality improvement team meetings to review data and act accordingly. In addition, they pointed towards individuals with dedicated quality improvement roles dedicated to the project. Finally, higher performing centers reported institutional culture was one that was conducive to quality improvement. They felt that their institution prioritized quality improvement and that they often had personal and productive working relationships across specialties.

Low performing centers felt that, although they often had interest and aspired to reduce CT, these efforts were hindered by a lack of academic time dedicated to quality improvement. Further, low performing centers did not have access to dedicated quality improvement personnel to support their efforts.

4. Discussion

Successful reduction in CT utilization for appendicitis diagnosis is a complex and multifactorial endeavor. Resource availability, implementation of protocolized care, effective multidisciplinary leadership, and an institutional culture of prioritizing quality improvement were important factors facilitating CT reduction. It is notable that apathy and misconceptions surrounding the risks of CT use in children were rarely reported barriers to CT reduction.

To our knowledge, this is the first study to qualitatively examine barriers and facilitators of CT reduction in pediatric appendicitis. Some of the barriers that we have identified in our qualitative analysis have been studied as the focus of published CT reduction quality improvement efforts. Single center initiatives, primarily at freestanding children's hospitals, to implement protocols for appendicitis diagnosis have demonstrated significant reductions in CT utilization and imaging costs without concomitant increases in negative appendectomy rates or worsening of patient outcomes [17-20,22,30,31]. Similarly, institutions that pivoted toward MRI for appendicitis workup have demonstrated that the implementation of MRI markedly reduced CT utilization [32]. However, the generalizability of such findings is unclear as it is unknown what additional institutional barriers that these centers had to overcome to enable successful implementation. Local contextual barriers to changes in practice may have significant effects precluding the success of a single solution. A recent multicenter cluster randomized trial demonstrated that the implementation of a clinical practice guideline was effective in reducing CT utilization for only a single health system, whereas the same effect was not seen in other participating institutions [33]. A qualitative study examining the barriers to implementation of evidence-based practice within pediatric surgery, also utilizing the TDF, identified similar results. Specifically pediatric surgeons reported time constraints and resource limitations as significant barriers to implementation while noting that the presence of a local champion was a useful facilitator [34]. These findings illustrate the heterogeneous challenges that pediatric surgeons face as they seek improve the delivery of care at their institution.

These findings suggest that a single solution for CT reduction is unlikely to be broadly applicable. If a quality improvement collaborative (QIC), like the PSQC, is to implement scalable change, then innovative and targeted approaches based on local context and resource availability will be necessary. While QICs may struggle to influence environmental barriers such as US availability or quality improvement infrastructure, QICs can leverage their combined experience via collaborative implementation strategies to address barriers and enact meaningful institutional change [35]. One commonly used implementation approach used by QICs is the Breakthrough Series Collaborative Model [36] which accelerates quality improvement through pooling the knowledge, skills, and resources of the QIC to target a specific clinical topic for improvement. The QIC then holds regular sessions learning sessions and conducts Plan-Do-Study-Act (PDSA) cycles to accelerate improvement, assess progress, and share experiences from successes and failures [37]. Using the PSQC and CT reduction as an example, members can share knowledge and experience regarding appendicitis diagnostic protocols or radiation reduction champion identification via distributed implementation bundles and learning sessions. Meanwhile, peer coaching can offer a more targeted and direct method of sharing experience on topics such as garnering leadership support and soliciting multidisciplinary involvement. A final benefit of QICs is the regular sharing and review of data. In this regard, by utilizing already abstracted NSQIP-Peds data, the PSQC aims to minimize as much as possible the threshold to initiating and monitoring a quality improvement project to reduce CT.

Despite these efforts, unless hospitals prioritize CT reduction, many institutional barriers will be difficult to overcome. While QICs can facilitate local QI initiatives, it lacks the power to regulate its participating institutions. Other external pressures will be critical in encouraging children's hospitals to improve their quality improvement infrastructure, invest resources in implementing alternative imaging modalities, and actively work to reduce CT utilization in the workup of pediatric appendicitis. Examples of such external pressures include reportable quality measures for CT use or institutional markers of high quality care such as the ACS Children's Surgical Verification Quality Improvement Program [38].

These findings should be interpreted in the setting of several limitations. First, this was a qualitative study involving only 13 children's hospitals. While participating institutions represented a mixture of free-standing children's hospitals and children's hospitals nested within larger health systems, the findings may not be generalizable to all settings where children are evaluated for abdominal pain and appendicitis. The facilitators and barriers of CT reduction in community non-children hospitals warrants further study as a significant proportion of CT scans for appendicitis occur in this setting. Second, while we attempted to be as inclusive as possible with regards to key stakeholders, not all focus groups were multidisciplinary, and none contained any hospital administration representatives or imaging technician viewpoints. Although we did reach thematic saturation, this limitation may limit the generalizability of our findings as we may have missed more nuanced themes by not including multiple stakeholders in all interviews. Ultimately, multidisciplinary focus groups often focused on the major themes discussed in our results. Finally, interviewees were made aware of the purpose of our focus groups and their answers may have been potentially biased (e.g., interviewees may have been less likely to express apathy or lack of knowledge regarding CT scans). Nonetheless, we attempted to gain perspectives from both high and low performing sites, from a variety of key stakeholders, and conducted interviews until thematic saturation was achieved.

5. Conclusions

Factors such as availability of alternative trusted imaging modalities (US or MRI), protocol implementation and adherence, local champions and leadership, and QI infrastructure play important roles in CT reduction for pediatric appendicitis. Efforts are required to equip hospitals to reduce their CT utilization in pediatric appendicitis and persuade leadership to prioritize quality improvement.

Previous communication

None.

Declarations of Competing Interest

None.

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Supplementary materials

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