Purpose

In the last 10 years alone, the number of computed tomography (CT) scans used in young children has tripled in the diagnostic evaluation of common pediatric complaints. This is despite overwhelming evidence that exposure to ionizing radiation in the young child increases the overall lifetime cancer risk. National organizations have recommended that efforts should be made to use different imaging modalities when possible and reduce CT radiation settings to minimize radiation exposure in the young child with immature organs and smaller size. Despite these well known facts and the potential harm to patients, the organization of many healthcare systems have created barriers that make reduction in CT utilization rate difficult. We aimed to develop a systematic approach to review the best evidence on the diagnostic evaluation for a child with potential appendicitis and reorganize our healthcare delivery system to predictably reduce radiation exposure. We sought to bring together stakeholders from multiple disciplines and through iterative PDSA cycles drive down the CT utilization rate in the diagnosis of acute appendicitis. In conjunction we aimed to validate the predictive strengths and limitations of the clinical exam and non-radiating imaging modalities (ultrasound) while also decreasing the number of children with missed diagnoses of appendicitis on their initial emergency department (ED) encounter.

Methods

Our institution had previously developed a proven method to review best evidence based practice and implement an evidence based guideline across our institution for common conditions (e.g. asthma) and sustain improved patient outcomes. We began with a review of our current rates of pre-operative CT utilization rate, our rates of “no imaging” prior to operations, and compared these rates to other large children’s hospitals through two collaborative data sharing networks (NSQIP and PHIS). A review of our practice and baseline imaging utilization rates showed opportunities for improvement in four major areas. This included use of an agreed clinical scoring tool to define risk stratification, creating a standard method of reporting ultrasound (US) results to clearly delineate equivocal findings, standardizing the criteria for ordering a CT scan in our department, and tracking balancing measures of the number of patients who were missed with the diagnosis of appendicitis on their initial ED encounter in our medical system.

Using GRADE methodology stakeholders developed clinical questions targeting high variability in clinical practice. An evidence review of over 75 articles then led to the creation of a multidisciplinary pathway towards the approach of a child with concern for appendicitis in the ED. Highlights of this pathway included the implementation of the Pediatric Appendicitis Score (PAS) for every child with an evaluation for appendicitis in the ED, setting expectations on surgical consultation for equivocal cases and for high risk cases that could proceed to an operation with no imaging, incorporating ultrasound as the initial imaging test for patients, standardizing radiology reports and technique on abdominal ultrasounds, and
standardizing pain control, labs and fluid resuscitation for these children during their ED stay.\textsuperscript{9–14} (Figure 1, Table 1)

Implementation and education of staff included the development of a “yellow sheet” that mandated that all pediatric patients with a potential appendicitis have a PAS score documented on the chart. Regular chart reviews were done to increase compliance of this tool until ED providers met this >90% of the time. To ensure the PAS score was achieving the same predictability as found in the literature, a chart review of over 600 charts was done to follow each patient’s PAS score to their final diagnosis. Similar methodology of chart review and score validation was done to ensure >90% compliance of the US scoring tool by radiologists. Finally, the emergency department implemented a system to review every patient for every diagnosis that returned to the ED for a second visit within 72 hours of their initial visit (i.e “bounce back rate”). Patients with a diagnosis of appendicitis were pulled out to be reviewed by the stakeholders of the workgroup to define opportunities for improvement and to give in person feedback to providers.

The workgroup defined 5 key metrics to create a dashboard for all hospital staff to review on the performance of the institution on the evaluation and management of children with appendicitis. (Table 2). PHIS data was used retrospectively to see how the bounce-back rate for patients with appendicitis in our institution changed compared to other large children’s hospitals in the nation.

Results

Implementation of our evidence based pathway showed a reduction of pre-operative CT utilization from a high of 30% down to a sustained median of 11%. Concurrently pre-operative US utilization rate rose from 47% to a high of 70% (Figure 2). Compared to the top 45 children’s hospitals in the nation (PHIS database), our hospital sustained a lower CT utilization than our peers and increased pre-operative US utilization rates to match those of peer institutions.(Figure 3)

Validation of the predictability and risk stratification of the PAS score showed similar performance to that quoted in the literature.\textsuperscript{13} (Figure 4) The appendectomy rate in the highest risk patients approached 95-100%, while 0% of patients with a low risk score (<3) had an appendectomy. This occurred while we reduced the bounce-back rate of patient’s missed diagnosis of appendicitis on their first visit and drove our rank to be the second best performing hospital in the nation compared to our peers in this metric (Figure 5).

Implementation of a standard US scoring tool by radiology further showed that patients with confirmed appendicitis or confirmed normal US achieved excellent true positive (96.3%) and false negative rates (0.72%) (Figure 6)

Throughout this project our institution was able to achieve best in class performance on all metrics in our dashboard (Figure 7)
Conclusion

Use of an evidence based method to create multidisciplinary consensus on best management for children with possible appendicitis can reducing ionizing radiation exposure while also decreasing the rate of missed diagnosis of appendicitis on the initial ED encounter. Continuous feedback to providers and iterative PDSA cycles can also hardwire in the implementation of new systems of risk stratification (PAS score) that validate the use of the clinical exam and encourage a streamlined approach in using diagnostic imaging. Standardized reporting of US imaging findings and tying them to the final appendectomy results further gave providers confidence in the use of modalities other than CT scan.

Despite the fact that evidence had supported the use of US over CT scan in the literature for over a decade, it was the organized process driven by meaningful data and engaged stakeholders that allowed for sustained delivery of reduced radiation while also ensuring adequate diagnosis on the initial ED encounter. While CT scan utilization overall was decreased, it is meaningful to note that previous literature has also shown that use of US alone does have clinical limitations\textsuperscript{15}

Iterative PDSA cycles also showed that in order to reduce variation across the hospital some key elements needed to be present. This included engaged stakeholders from all disciplines that encounter these patients, meaningful data to validate the use of a new process to reluctant providers and hardwired system changes that used old systems (paper sheets to track patients) when institutional EMR systems could not provide timely and adaptive changes to implement a new process.

Further steps in this project now include a focus on pediatric patients evaluated for appendicitis at institutions outside of our children’s hospitals for possible appendicitis. Chart review has shown that on average these patients had a rate of pre-operative CT utilization rate of 70% prior to transfer to our hospital for appendectomy (Figure 8). This number of patients likely represents only a fraction of the pediatric patients undergoing CT scan since this review was only of patients who ultimately had appendicitis. Our workgroup is currently engaging stakeholders across the healthcare network in institutions with little pediatric expertise to create a standardize risk stratification system across the city to funnel those patients needing imaging or immediate operative repair to our institution. Our next aim is to demonstrate that we can replicate similar results and drive down pre-operative CT utilization rates at non-children’s hospital facilities.
Figure 1 – Evidence Based Pathway for Possible Acute Appendicitis in Children

Acute Appendicitis Postoperative Pathway
Evidence Based Outcome Center

Acute inflammation (or normal)
- No further antibiotics
- Discharge in 24 hours
- Discharge instructions

Perforated
- Piperacillin/Tazobactam (Ziagen™) or Ceftriaxone/Metronidazole (Flagyl™)

Gangrenous
- 24 - 48 hours IV
- Piperacillin/Tazobactam (Ziagen™) or Ceftriaxone/Metronidazole (Flagyl™)

APSS Criteria
- Antibiotics 24 hours
- Pain controlled with oral meds
- Eating regular diet
- No fevers or passing flatus

Addendum 6
Discharge instructions

Culture all abscesses

CT or drain
+ Abscess
CT scan on postoperative day 6 or 7
- Consider PICC

Manage Off Pathway

APSS criteria met in ≤ 5 days

+ Phlegmon
Change to oral antibiotics if total ≥ 7 days

Discharge on IV when APSS criteria are met
- Follow up with surgeon in one week

Amoxicillin (Clavulanate (Augmentin™)), Augmentin™/Metronidazole (Flagyl™)
or Sulfamethoxazole/Trimethoprim (Bactrim™)

Discharge instructions

For questions concerning this pathway, please visit dell children's
Last Updated: July 5, 2018
### Table 1 – Standardized Radiology US Scoring Tool for Limited Pediatric Abdominal Ultrasound

**Ultrasound Scoring**

*Negative ultrasound:*
1 = Normal completely visualized appendix
2 = Partially-visualized appendix - no findings to suggest appendicitis

*Equivocal Ultrasound*
3 = Non-visualized appendix - no findings to suggest appendicitis
4 = Equivocal study - e.g. peri-appendiceal inflammation or borderline appendiceal enlargement but otherwise normal appendix

*Positive Ultrasound*
5 = Appendicitis (with or without abscess)

**Standard reporting components:**

EXAM: Limited abdominal ultrasound

CLINICAL HISTORY: [Abdominal pain - concern for appendicitis]

**FINDINGS:**

_**Appendix:**_
- Visualized: [Completely]
- Fluid-filled: [No]
- Compressible: [Yes]
- Maximum diameter with compression (outer wall to outer wall): [ ]
- Appendicolith: [No]
- Wall:
  - Hyperemia: [No]
  - Thickening (>2 mm): [No]
  - Loss of mural stratification: [No]

Free Fluid: [Physiologic]
- Increased conspicuity of peri-appendiceal fat: [No]
- Abscess: [No]
- Additional findings: [None]
<table>
<thead>
<tr>
<th>Table 2 – Adherence Measures for Pediatric Appendicitis Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Compliance with ACR recommendations:</td>
</tr>
<tr>
<td>I. Number of patients that present to the emergency</td>
</tr>
<tr>
<td>department with an appendectomy procedure and CT imaging</td>
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<tr>
<td>preceded by US imaging</td>
</tr>
<tr>
<td>II. Pediatric appendicitis score utilization:</td>
</tr>
<tr>
<td>I. Number of patients presenting to the emergency</td>
</tr>
<tr>
<td>department with an appendectomy procedure that have a</td>
</tr>
<tr>
<td>documented Pediatric Appendicitis Score in the EMR</td>
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<tr>
<td>III. Preoperative CT utilization:</td>
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<tr>
<td>I. Number of patients that present to the emergency</td>
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<tr>
<td>department with an appendectomy procedure with preoperative</td>
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<tr>
<td>CT imaging</td>
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<tr>
<td>IV. Ultrasound radiology score accuracy:</td>
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<tr>
<td>I. Number of patient that have an appendectomy procedure</td>
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<td>with a Radiology Appendicitis Score of 5</td>
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<tr>
<td>V. Ultrasound radiology score false negative rate:</td>
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<tr>
<td>I. Number of patients that have an appendectomy procedure</td>
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<td>with a Radiology Appendicitis Score of 1</td>
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</table>
Figure 2 – Prooperative CT and US utilization rates

Ultrasonography & Computed Tomography rates for patients presenting in the emergency department with an appendicitis diagnosis & appendectomy procedure code at DCMCCT (2013-2016)

- CT Utilization
- US Utilization

Legend:
- CT Utilization
- US Utilization
Figure 3 – Comparative pre-operative CT and US utilization rates with PHIS pediatric hospital network
Figure 4 – Validation of the Pediatric Appendicitis Score
Figure 5 – DCMC ED Bounceback rate compared to peer PHIS hospitals
Figure 6 – Validation of Standardized Pediatric Abdominal US Scoring System
### Figure 7 – DCMC Workgroup Appendicitis Dashboard

#### Q3

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Compliance with ACR (%)</th>
<th>Pediatric Appendicitis Score Utilization (%)</th>
<th>Preoperative CT Utilization (%)</th>
<th>Ultrasound Radiology Score Accuracy (%)</th>
<th>Ultrasound Radiology Score False Negative Rate (%)</th>
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<tbody>
<tr>
<td>Compliance with ACR (%)</td>
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<td>94.00</td>
<td>13.70</td>
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<td>Pediatric Appendicitis Score Utilization (%)</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Preoperative CT Utilization (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ultrasound Radiology Score Accuracy (%)</td>
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#### Compliance with ACR (%), Pediatric Appendicitis Score Utilization, Preoperative CT Utilization, Ultrasound Radiology Score Accuracy, Ultrasound Radiology Score False Negative Rate

<table>
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<tr>
<th>Year</th>
<th>Month</th>
<th>Compliance with ACR (%)</th>
<th>Pediatric Appendicitis Score Utilization (%)</th>
<th>Preoperative CT Utilization (%)</th>
<th>Ultrasound Radiology Score Accuracy (%)</th>
<th>Ultrasound Radiology Score False Negative Rate (%)</th>
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</tbody>
</table>
Figure 8 – Preoperative CT and US utilization rate for Appendectomy Diagnosis, Children’s Hospital vs Non-Children’s Hospitals
Works Cited


8. GRADE home [Internet]. [cited 2017 Jan 19];Available from: http://www.gradeworkinggroup.org/


