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Cost-Effectiveness of Integrating a Clinical Decision Rule and Staged Imaging Protocol for Diagnosis of Appendicitis

Sean Gregory, MBA, MS, PhD[1,*], *Karen Kuntz, ScD*[2], *François Sainfort, PhD*[2], *Anupam Kharbanda, MD, MSc*[3]

[1]*Department of Health Policy and Management, College of Public Health, and Department of Pediatrics, Morsani College of Medicine, University of South Florida, Tampa, FL, USA;* [2]*Department of Health Policy and Management, School of Public Health, University of Minnesota, Delaware, MN, USA;* [3]*Pediatric Emergency Medicine, Children's Hospital and Clinics of Minnesota, Minneapolis, MN*

ABSTRACT

Objective: To evaluate the cost-effectiveness of a diagnostic protocol for appendicitis in children, the use of a validated clinical decision rule (CDR) and a staged imaging protocol, compared with usual care. **Methods:** We estimated the cost-effectiveness of the three competing strategies using parameters from existing literature as well as a Markov model developed to simulate the effects of exposure to ionizing radiation from a single computed tomography (CT) study in the course of diagnosis. The simulation model was applied to a hypothetical cohort of 100,000 boys and girls, age 10 years, presenting with acute abdominal pain to emergency departments in the United States. **Results:** The integrated strategy, the CDR followed by staged imaging, was found to be the most cost-effective approach. Cost savings accrued from the reduction in CT utilization for low-risk patients compared with the other two strategies. The addition of ultrasound (US) to the CDR strategy reduced CT utilization by an additional 10.9%, its main cost advantage, with negligible change in net health benefits from false-negative US results, and associated morbidity or mortality. **Conclusions:** Results suggest that the integration of staged imaging with the CDR for the diagnosis of appendicitis in children is a cost-effective and cost-saving approach. The model estimates a further 10.9% reduction in the number of CTs from the incorporation of US for patients scoring high or medium risk, in excess of the 19.5% reduction estimated in the CDR validation study.
Keywords: appendicitis, computed tomography, cost-effectiveness, decision rule, diagnosis.

Introduction

Appendicitis is a common pediatric emergency condition for children presenting to emergency departments (EDs). Complaints of abdominal pain account for 5% to 10% of all pediatric ED encounters [1–4]. Appendicitis is the most common indication for emergency surgeries among children [5], and remains difficult to diagnose because of the similarity of symptoms with those of other illnesses [1,6]. Missed or delayed diagnosis increases the risk of morbidity and mortality resulting from perforation of the appendix [3,6–8]. Computed tomography (CT) improves diagnostic accuracy, but exposes children to high doses of radiation, a risk factor for the development of cancers [9,10]. The increasing use of CT for the diagnosis of illnesses in children, including appendicitis, has raised concerns regarding the effects of radiation exposure from these imaging studies [9–13].

Several investigators have proposed a staged imaging protocol to reduce the utilization of CT, whereby diagnosis starts with an ultrasound (US) and proceeds to a CT study only if the US results are negative or equivocal [9,11,12,14–16]. Kharbanda et al. [17,18] developed and validated a clinical decision rule (CDR) to enhance clinicians' diagnostic ability and guide choices concerning when to use CT. The goal of this study was to develop and implement a decision analytic model to quantify the benefits, costs, and harms of various diagnostic approaches for children with suspected appendicitis considering a validated CDR and a staged US and CT (S-US/CT) imaging protocol.

The use of decision analysis to examine diagnostic approaches for children with suspected appendicitis has appeared in the literature over the past 35 years [17–21]. Both Neutra [19,22] and Alvarado [20] developed early decision rules on the basis of symptoms and limited diagnostic tests (e.g., leukocytosis). Their work, however, predated CT imaging technology. Concerned with the risks presented by CT imaging, Kharbanda et al. [17] developed and validated [18] a new CDR to identify children at low risk for appendicitis who should not be referred to imaging, thereby reducing exposure to unnecessary radiation. The CDR was tested and validated in a separate study, which estimated a 19.5% reduction in CT imaging [18].

Hagendorf et al. [21] compared the effectiveness of observation, US, and CT and concluded that referral to CT was the optimum diagnostic strategy for all patients presenting with

* *Address correspondence to:* Sean Gregory, Department of Health Policy and Management, College of Public Health, University of South Florida, 13201 Bruce B Downs Boulevard, MDC 56, Tampa, FL 33616.

E-mail: seangregory@health.usf.edu.
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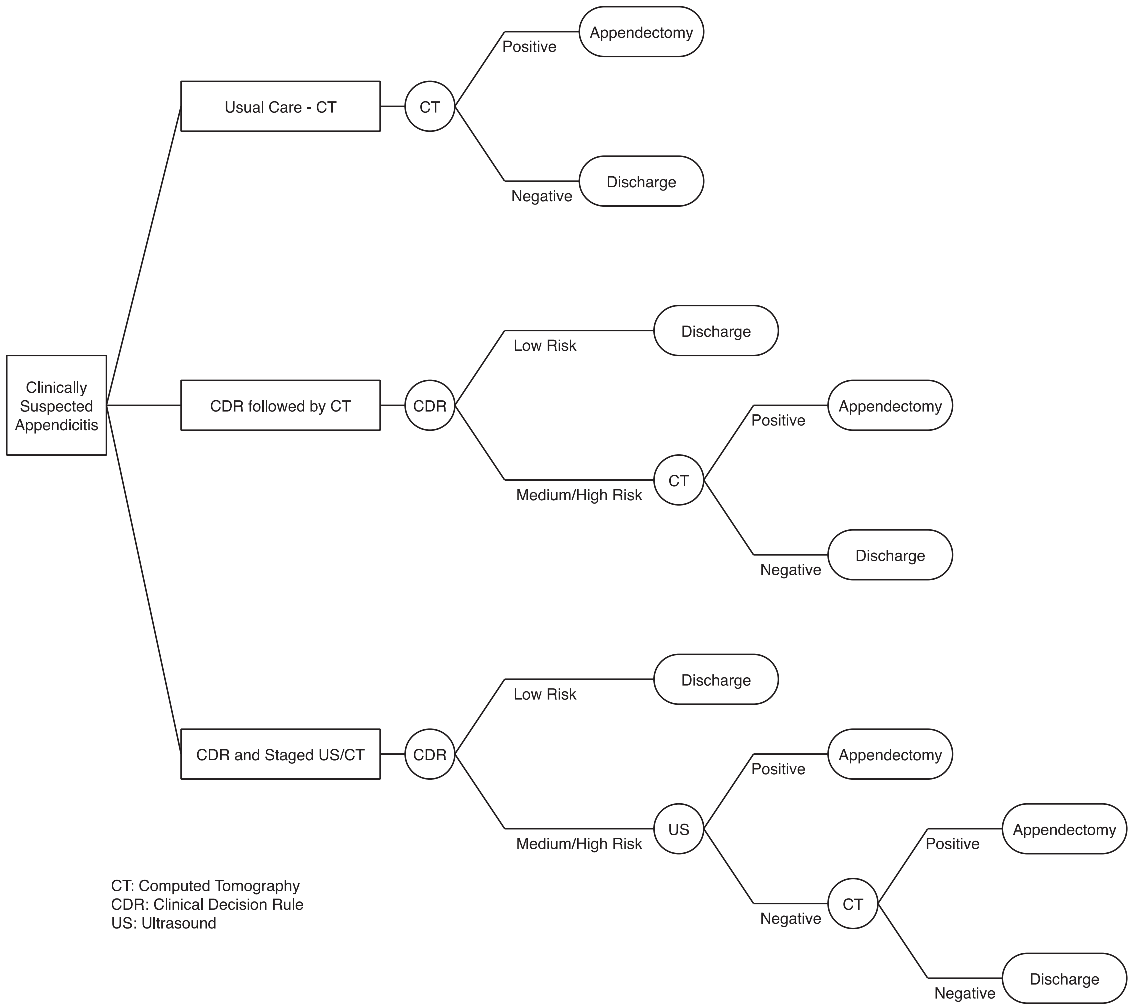

Fig. 1 – Decision tree of short-term events in the model. CDR, clinical decision rule; CT, computed tomography; US, ultrasound.

symptoms of appendicitis. Their analysis, however, 1) lacked the incorporation of the potential harms of ionizing radiation exposure from CT, 2) did not consider newly proposed S-US/CT imaging protocols, and 3) did not include the use of validated CDRs to augment and assist clinicians in their referral for imaging and ultimately their diagnosis of appendicitis.

To this end, we compared three strategies: 1) the usual care strategy (Usual Care), which represents a CT rate of 55%, consistent with the current rate reported in clinical practice [13]; 2) the CDR/CT strategy [18], indicating CT only for patients classified as medium/high risk by the CDR; and 3) the integrated strategy consisting of the CDR followed by a S-US/CT imaging protocol (integrated strategy), indicating US for patients scoring medium/high, followed by CT if US is negative or equivocal.

Methods

Conceptual Model

Our model is comprised of two components: 1) a decision analytic model that incorporates the validated CDR [18], as well as the staged imaging protocol [12], and 2) a Markov model, adapted from Wan et al. [23] to estimate long-term clinical and economic outcomes. As shown in Figure 1, the decision tree displays a choice between the three mutually exclusive strategies described above: Usual Care, CDR/CT, and the integrated strategy. In constructing the model and designing and executing the analyses, we referred to the Consolidated Health Economic Evaluation Reporting Standards guidelines [24].

Because radiation-induced cancer risks are not empirically known, we used a Markov model to estimate radiation-induced cancer risks resulting from CT. Figure 2 depicts the Markov process and displays the three health states and possible transitions following exposure to CT. Because cancer incidence and mortality, as well as background mortality, vary by sex, analyses were performed for girls and boys separately.

To evaluate the three competing strategies, we used the model to conduct a Monte-Carlo simulation of 100,000 hypothetical boys and girls, on a yearly cycle from age 10 years until death or 100 years, whichever occurs first. Where possible, we used probabilistic parameters found in the literature, and used them to develop distributions of the underlying parameter. With each of the 100,000 simulations, the model drew a parameter from the distribution, such that the overall analysis incorporated the underlying uncertainty regarding the input parameters. In the absence of distributional information available in the literature, deterministic model parameters were used. The parameters used, whether probabilistic or deterministic, are indicated in the summary of parameters in Table 1.

The three strategies were first compared on the basis of estimated net health benefits, quality-adjusted life-years

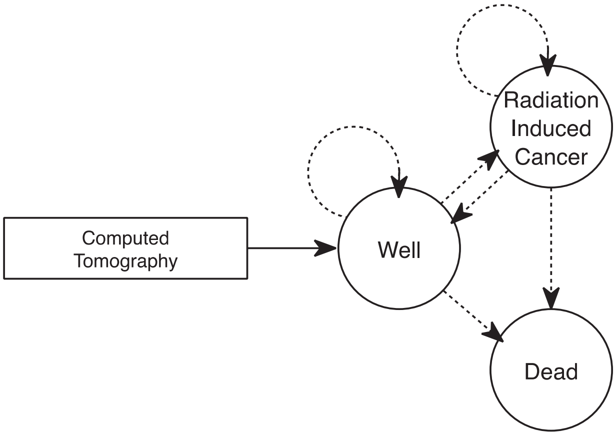

Fig. 2 – Chart of Markov process showing health states and transitions following exposure to computed tomography.

(QALYs). We then used the results to evaluate the cost-effectiveness of the strategies [25–27]. A 3% rate was applied to calculate discounted QALYs and costs, per the recommendations of Gold [25]. We used willingness-to-pay (WTP) thresholds of both $50,000 and $100,000 per QALY, suggested by both Gold [25] and Drummond et al. [26], and assessed cost-effectiveness from a payer's perspective. Finally, we assessed the results in a sensitivity analysis using key model parameters. Models and analyses were developed and simulated using Tree Age Pro 2014 (Waltham, MA) decision analytic software.

Model Parameters: CDR, Markov Model, and Cost-Effectiveness Parameters

Most parameters used in this study were derived from Wan et al. [23], allowing us to directly compare our findings. We performed a systematic review of the literature and data sources, post-2009, to update parameters, if available, and identify best possible estimates, as well as ranges, necessary for the model. Costs were inflated from the year of their publication to year 2014 using the Medical Care component of the Consumer Price Index. All input parameters for the model, other than mortality data, are provided in Table 1 and further described below [28–34].

Sensitivity and specificity of the CDR, US, CT, and CT after negative/equivocal US are provided in Table 1. The CDR stratifies patients presenting with appendicitis symptoms into two strata —low risk and high/medium risk [17,18,35]. The CDR performs well, and was recently validated in a clinical setting demonstrating a sensitivity of 98.1% and a specificity of 23.7% [18]. All patients classified as low risk follow a watchful waiting strategy with no diagnostic imaging. The test characteristics, along with the prior probability of appendicitis, are used to determine the number of children in each of the following groups: true positive, true negative, false positive, and false negative, with respect to their appendicitis diagnosis. This classification is then compared across each of the three competing strategies. The prior probability of appendicitis used in this analysis was 0.388 [18]. This differs from estimates used in other studies [21,23], which use estimates in the 0.50 to 0.60 range and correspond to probabilities of disease upon referral to a surgeon for consultation. The goal of this study was to recommend a strategy for use by an emergency medicine physician upon presentation of a patient with

Table 1 – Parameters.

Category	Parameter	Value ± SD	Distribution	Reference
Clinical Decision Rule (CDR)	Prior probability of disease (SE)	0.388 ± 0.0063	Beta	[18]
	Sensitivity (SE)	0.981 ± 0.0037	Uniform	[18]
	Specificity (SE)	0.237 ± 0.0067	Uniform	[18]
Ultrasound (US)	Sensitivity	0.88	Gamma	[31]
	Specificity	0.94	Gamma	[31]
Computed tomography (CT)	Sensitivity	0.94	Uniform	[31]
	Specificity	0.95	Uniform	[31]
	Base rate of CT	0.55	Beta	[13]
	(SE)	0.10		
CT after negative/equivocal US	Sensitivity	0.97	Uniform	[12]
	Specificity	0.94	Uniform	[12]
Appendectomy sequelae	Perforation at presentation	0.387	Uniform	[6]
	Perforation after missed diagnosis	0.774	Uniform	[6]
	Mortality from Disease Positive	0.00240	Uniform	[8]
	Mortality from perforation	0.01660	Uniform	[8]
	Mortality appendectomy	0.00140	Uniform	[8]
Utilities	Acute appendicitis	0.73	Uniform	[27]
	Well	0.88	Uniform	[28]
	Cancer	0.74	Uniform	[28]
Costs (2013$)	Ultrasound	430	Uniform	[29]
	CT	1,017	Uniform	[29]
	Appendectomy	13,049	Uniform	[6]
	Appendectomy with perforation	25,279	Uniform	[6]
	Bladder cancer	113,006	Uniform	[29]
	Breast cancer	98,926	Uniform	[29]
	Colon cancer	58,280	Uniform	[30]
	Leukemia	61,291	Uniform	[31]
	Lung cancer	57,227	Uniform	[29]
	Stomach cancer	35,375	Uniform	[29]

CDR, clinical decision rule; SE, standard error.

Table 2 – Results of Monte-Carlo simulation.

Strategy	Females			Males		
	QALYs	Discounted* QALY	Discounted costs ($†)	QALYs	Discounted QALY	Discounted costs ($†)
Integrated strategy	65.6106	27.5587	2177	61.1153	26.7580	2201
CDR/CT	65.6168	27.5598	2607	61.1388	26.7604	2639
Usual Care	65.5947	27.5484	6008	60.1044	26.7514	5993

CDR, clinical decision rule; CT, computed tomography; QALY, quality-adjusted life-year.
*3% discount rate used for QALYs and costs, per Gold [25].
†2014 US dollars.

appendicitis-like symptoms at a typical ED, thus the lower prior probability of disease.

The Markov model, adapted from Wan et al. [23], is used to estimate the harms associated with CT. The model consists of three health states (well, cancer, and death) and simulates the incidence of radiation-induced cancer for children exposed via a single CT study. It then estimates the resulting costs and mortality, compared with the background mortality for unexposed children, using standard US life tables downloaded from the National Center for Health Statistics [36]. In the Markov model, all children with appendicitis experience the corresponding disease utility for a period of 1 month. We used a straight-line interpolation method to calculate age-specific utilities for the cancer and the well state varied by age.

Cancer Incidence, Mortality, and Background Mortality

For the purpose of this study, the incidence of radiation-induced cancers from exposure to CT for diagnosis of appendicitis was required. The goal was to quantify the incremental incidence of radiation-induced cancers for those receiving a CT for appendicitis diagnosis. Surveillance, Epidemiology, and End Results (SEER) Program to extract cancer incidence by age for six cancer sites [37]. Wan et al. [23] estimated the lifetime attributable risk (LAR) resulting from a single diagnostic CT for appendicitis diagnosis at 20.4 per 100,000 and 26.1 per 100,000 for males and females, respectively. To incorporate the LAR estimates into our model, we estimated the proportion of the total cumulative incidence rate for the age at diagnosis, and used that age-specific proportion to compute the amount of LAR at each age. The result was an annual probability of radiation-induced cancer by age. In addition, following the approach by Wan et al. [23], we incorporated a 2-year delay for the onset of cancer resulting from exposure to CT.

We derived cancer-specific mortality rates using 5-year relative survival probabilities for each of the six cancer sites as reported by SEER. The cancer-specific mortality rates were combined into a single annual cancer mortality rate using a weighted average of the individual cancer site mortalities, based on their respective prevalence rates found in SEER. This additional cancer-specific rate was added to the background, age-specific, mortality rate using the 2006 U.S. life tables available from the National Center for Health Statistics [36].

Sensitivity Analyses

To assess the robustness of our results to uncertainty in model parameters and variance in clinical contexts, we conduced a probabilistic sensitivity analysis, using distributions for the six probabilistic parameters and uniform distributions for the remaining deterministic parameters.

Three parameters represented the greatest potential threat to the study's results: 1) prior probability of disease, 2) rate at which children receive CT for these symptoms in Usual Care, and 3) the sensitivity of US to detect appendicitis. Based on our a priori assessment of the diagnostic process used in practice, we conducted a three-way sensitivity analysis of these parameters to determine their impact on our results.

The setting of the study, presentation of abdominal pain in the ED, is different than others presented in the literature, such as referral to a surgeon for consult [21,23]. These two settings have differing prior probabilities of disease, with the ED often being the first clinical encounter where a child is assessed—thus a lower probability of disease is assumed—before clinical assessment [18]. Referral to a surgeon occurs after an initial clinical examination in the ED or by a physician in an outpatient setting, thus assumes a higher prior probability of disease [21,23]. To assess the sensitivity of our results to these noted differences in prior probability of disease, we varied this parameter from 0.1 to 0.8.

Recent efforts have focused on reducing the use of CT, specifically for the diagnosis of appendicitis [38]. Considering the relatively high rate of use in Usual Care, 55%, we wanted to assess the impact of overall clinical efforts on reducing the use of CT for diagnosis in Usual Care. We examined such effects on our results by varying the rate at which children receive a CT for these symptoms across a large range (0.1–0.8).

US sensitivity is particularly susceptible to variations in technician experience, competency and availability, as well as the type of ED, community or pediatric-specific [39]. To address this concern, we varied the US test characteristic, sensitivity, from 0.50 to 0.94, an illustrative lower bound, less than that reported in a recent study [24], and the upper bound equivalent to that of a CT examination [40].

Results

Results of our analyses are first presented in terms of net health benefits for the three strategies. Next, we examine discounted costs and then the cost-effectiveness of the competing strategies. Finally, we present a sensitivity analysis of our findings based on the variance in key model parameters.

Net Heath Benefit—QALYs

Estimates of QALYs and discounted QALYs, for 10-year-old girls and boys, are presented in Table 2 for each of the three strategies. The Usual Care strategy is inferior to both the CDR/CT strategy and the integrated strategy, for both boys and girls, and is therefore excluded from further analysis. For girls, the CDR/CT strategy is superior to the integrated strategy by adding a predicted .0011 discounted QALY, equivalent to 0.4 quality-adjusted life-day. The results for boys follow a similar pattern,

wherein the CDR/CT strategy is superior by 0.0024 discounted QALY (0.9 quality-adjusted life-day) over the integrated strategy. In terms of clinically significant net health benefits, the integrated strategy and CDR/CT are essentially equivalent.

Costs

The most notable differences between the competing strategies are the discounted costs, summarized in Table 2. The integrated strategy is 19% less costly than the CDR/CT, for both boys and girls. These costs differences are primarily attributable to the reduction in the number of children receiving a CT in the integrated strategy versus the CDR/CT strategy, eliminating unnecessary CTs, and instead relying on the CDR and/or US for diagnosis. Cost savings accrue from reductions in CT utilization, perforations, and negative appendectomies, more so than from the relatively small cost savings from the decreased risk of cancer later in life associated with fewer CT examinations.

As noted, a primary driver of cost differences among the strategies is the utilization of CT imaging. The integrated strategy results in the lowest CT utilization, 24.6% of the simulated cases, versus 35.5% for the CDR/CT and 55% in Usual Care. The integrated strategy offers a 10.9% further reduction in CT utilization over the CDR/CT strategy. In addition, the integrated strategy benefits by inheriting the high sensitivities of Kharbanda et al. CDR [18], US [34], and US followed by CT [9,11,12].

Cost-Effectiveness

Results from the analysis varied by sex, but the conclusion was identical; the integrated strategy is estimated to be the most cost-effective using either WTP threshold. Results are summarized in Table 3, and depicted in Figure 3. For girls, although the CDR provides a small 0.0011 discounted QALY gain over the integrated strategy, it does so at an incremental cost-effectiveness ratio of $390,909, significantly higher than either WTP threshold [25,26]. In the case of boys, the integrated strategy offers a nominal net health benefit gain of 0.0024 discounted QALY, but an incremental cost-effectiveness ratio of $182,500, again higher than prevailing WTP thresholds.

Sensitivity Analyses

We performed a probabilistic sensitivity analysis on our findings to determine how robust our findings were to changes in model parameters. The results are depicted in Figure 4, a scatterplot of results, and in Figure 5, a tornado plot of probabilistic parameters. The integrated strategy maintains superiority over the CDR/CT strategy in essentially all trials in the probabilistic sensitivity analysis, as depicted in Figure 5. There were a small number of trials in which the CDR/CT strategy achieved a superior result.

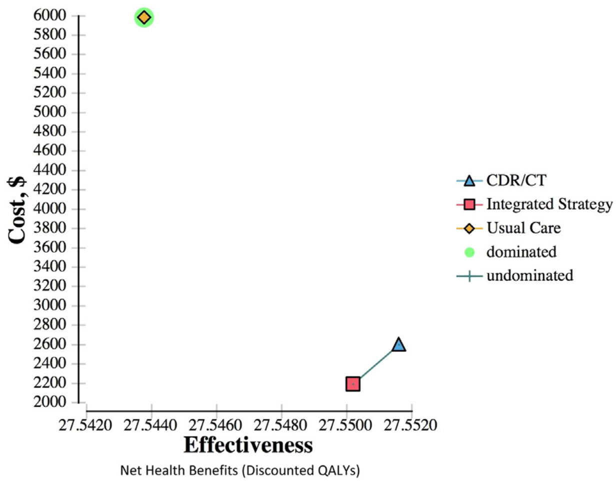

Fig. 3 – Cost-effectiveness results. CDR, clinical decision rule; CT, computed tomography; QALY, quality-adjusted life-year. (Color version of figure is available online.)

The three-way sensitivity analysis revealed how changes in two of the three primary parameters affected the superiority of the integrated strategy versus the CDR/CT strategy: 1) a small range of prior probability of disease, namely, 0.22 to 0.27; and 2) improvements in the sensitivity of US to detect disease, from 0.88 to 0.92. There were no conditions in which the Usual Care strategy was superior. The third variable in the sensitivity analysis, the base rate of CT in the Usual Care strategy, did not influence the choice between the integrated strategy and the CDR/CT strategy across the CT rate range used in the sensitivity analysis (0.1–0.8).

Table 4 depicts the results of the three-way sensitivity analysis, specifically indicating the thresholds at which the integrated strategy is superior to the CDR/CT strategy. At the lower bound of this analysis, the integrated strategy outperforms the CDR/CT strategy at high levels of prior probability of disease, greater than 0.425. At a US sensitivity equivalent to that of CT, the integrated strategy outperforms across a reasonable range of prior probability of disease of 0.20 or greater. The CDR/CT strategy outperforms the integrated strategy at low levels of prior probability of disease, less than 0.27, significantly lower than those reported in the validation study for the decision rule of 0.38 [18].

Table 3 – Cost-effectiveness analysis.

Strategy*	Discounted cost (US $)	Incremental cost (US $)	Effectiveness (discounted QALYs)	Incremental effectiveness	Incremental cost-effectiveness ratio (ICER)	Cost-effectiveness ratio
Females						
Integrated strategy	2177		27.5587			78.9950
CDR/CT	2607	430	27.5598	.0011	390,909	94.5943
Males						
Integrated strategy	2201		26.7580			82.2558
CDR/CT	2639	438	26.7604	0.0024	182,500	98.6159

CDR, clinical decision rule; CT, computed tomography; QALY, quality-adjusted life-year.
*Excludes dominated strategy (Usual Care).

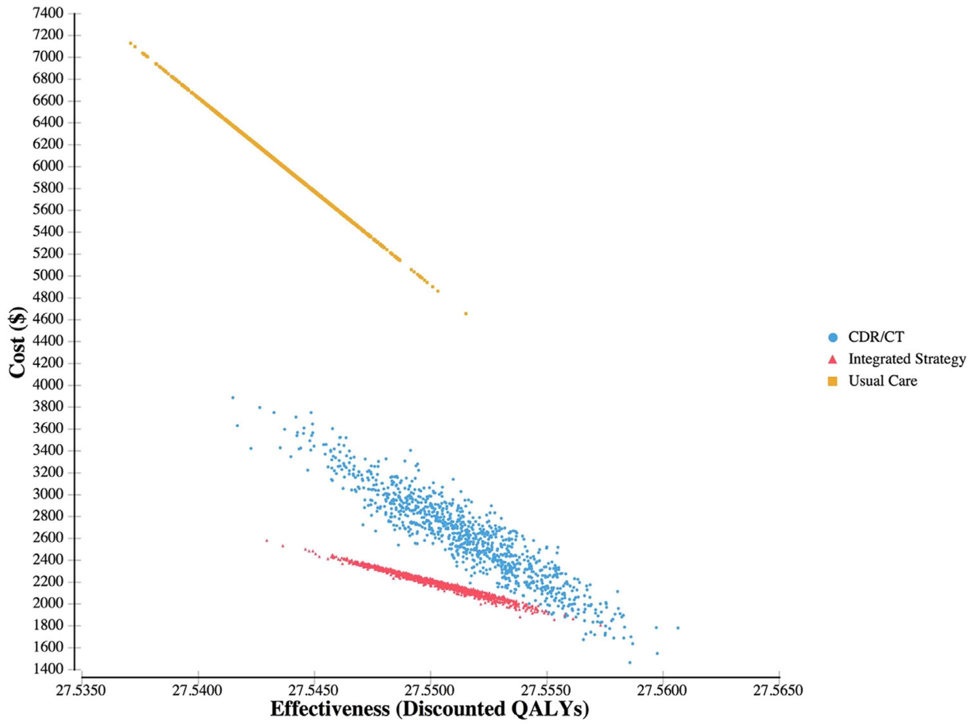

Fig. 4 – Scatterplot of probabilistic sensitivity analysis results. CDR, clinical decision rule; CT, computed tomography; QALY, quality-adjusted life-year. (Color version of figure is available online.)

Discussion

Our analysis found that the integrated strategy provided superior cost savings, without clinically significant net health benefit differences, at both WTP thresholds. This cost-saving result accrues from three areas: 1) the reduction in CTs for low-risk patients compared with the two other strategies; 2) the use of US first to confirm diagnosis, thus reducing the need for CT; and 3) the reduction in sequelae associated with acute perforation from misdiagnosis and watchful waiting, negative appendectomies, and long-term cancer risk, particularly among girls.

These findings are consistent with those from the previous literature, where the addition of US before CT results in

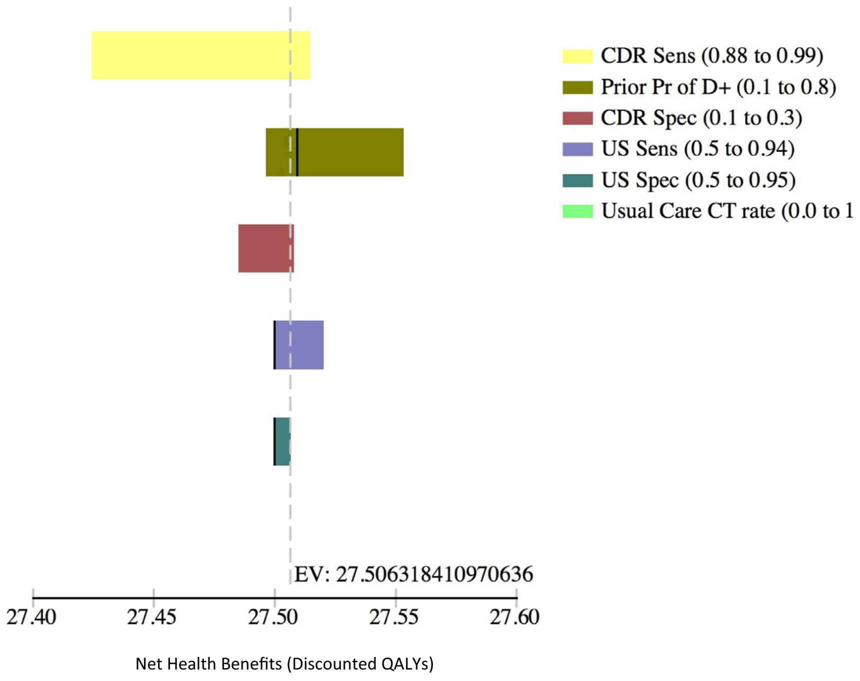

Fig. 5 – Sensitivity analysis tornado plot (net health benefits). CDR, clinical decision rule; CT, computed tomography; D+, disease positive; Pr, probability; QALY, quality-adjusted life-year; Sens, sensitivity; Spec, specivity; US, ultrasound.

Table 4 – Choice between integrated strategy and CDR: three-way sensitivity analysis..

Model parameter	Prior probability of appendicitis*
US sensitivity (USS) at 0.88	>0.27
USS raised to 0.92	>0.22
USS raised to equal CT (0.94)	>0.20
USS lowered to 0.50	>0.425

CDR, clinical decision rule; CT, computed tomography; ED, emergency department; US, ultrasound.
* This column contains the prior probability of appendicitis, upon presentation to the ED, as assessed by the attending emergency medicine physician. The superiority of the integrated strategy vs. the CDR/CT strategy varies by the sensitivity of US only; the base rate of CT does not change the choice of strategy across the range (0.1– 0.8).

substantial cost savings, without meaningful changes in effectiveness [23]. The contribution to the diagnostic literature is our demonstration of the benefits of the integrated strategy, implementing both the CDR and staged imaging protocol. Furthermore, the model estimates an additional 10.9% reduction in the use of CTs resulting from the integrated strategy, beyond the 19.5% reduction reported in the CDR model validation [18]. This result benefits from the high sensitivity and specificity of US in diagnosing disease. These results include considerable costs savings, with little harm from delayed or missed diagnosis.

The integrated strategy can be reasonably adopted and implemented as a clinical pathway for the diagnosis of appendicitis in children presenting to EDs [14–16]. Implementation of the integrated strategy poses an additional question: would surgeons receiving a referral for appendicitis from an emergency medicine physician, based on the decision rule and a positive US, continue to surgery, or would they order a CT as part of the preoperative procedure? If the surgeon would order a CT for a large percentage of surgical referrals, the benefits of incorporating US would be greatly reduced. This is an important policy concern for the promulgation of these types of decision aids into standard practice. Although they provide the best synthesis of scientific and clinical knowledge to diagnose a disease that is well regarded as challenging, would the protocol be followed through to surgery? Another important clinical concern, not accounted for in this analysis, is the potential sequelae from the use of intravenous contrast during CT studies, and the benefits to children from reducing this exposure.

Emerging studies regarding the use of magnetic resonance imaging for diagnosis of appendicitis offer an alternative to CT that eliminates the risks from ionizing radiation and has better accuracy [5]. Although magnetic resonance imaging has the potential to reduce the harms associated with exposure to ionizing radiation, there is no evidence of its cost-effectiveness versus CT, US, or the CDR. Further research is required to assess the true test characteristics of magnetic resonance imaging for the diagnosis of appendicitis and then perform an updated cost-effectiveness analysis to compare it to the integrated strategy identified in this study.

Study Limitations

This model is limited by the Usual Care strategy, in that it does not provide any insight into the diagnostic protocol used by physicians, its test characteristics, yet uses the same prior probability of disease. In light of the paucity of evidence regarding the sensitivity and specificity of the Usual Care strategy, there is potential for bias. The 55% rate of CT reported [13] suggests some diagnostic pathway of physical examination and history, used by physicians to determine which children are of high enough risk to merit a CT examination. An alternative would be to parameterize the Usual Care strategy as a CT-all strategy in which all children presenting with like symptoms receive CT examination. This strategy, although empirically intuitive, was, in our judgment, less appealing than using the current rate of CT examination as the key parameter for the Usual Care strategy. We performed this analysis and found that the Usual Care strategy became less cost-effective, and that the integrated strategy remained preferred in terms of cost-effectiveness at both WTP thresholds. Considering this issue, we feel that this potential bias would result in the Usual Care strategy being less effective and more costly. Evidence from the Kharbanda model validation, which used the same Usual Care strategy, suggests that the CDR would outperform the Usual Care strategy, and consequently the findings that the integrated strategy dominates the CDR remains a valid conclusion.

Our simulation not only incorporated probabilistic parameters of six parameters available in the literature but also relied on deterministic parameters for the balance of model parameters, where no distributional information was available. This is a limitation of our model and results, given that the variation in the uncertainty of deterministic parameters was not incorporated into the model, potentially biasing the results. For instance, these findings are subject to known variances in the sensitivity of the US test characteristics resulting from the experience and skill of the US technician [5,39]. Variances in the experience of US technicians can dramatically alter the value of the US findings and interpretation. Furthermore, the availability of US technicians to conduct studies, either in the ED or in diagnostic imaging departments based on ED physician orders, across shifts may hinder the widespread adoption of this protocol [5,39]. Our sensitivity analysis suggests little change in conclusions across reasonable changes in the sensitivity of US, from 0.88 to 0.94, equivalent to CT. Substantial changes in US test characteristics due to variance among technicians, however, pose threats to these conclusions.

Three factors would be crucial to the successful implementation of this protocol in practice: 1) the availability of pediatric US technicians across shifts; 2) the reduction in variance of experience and skill among technicians [5,39]; and 3) the acceptance of these diagnostic findings by surgeons as they consider appendectomy for positively diagnosed children presenting to the ED. A lack of confidence in findings from the integrated strategy by surgeons may result in ordering of additional confirmatory CTs before surgery, thus adding costs and changing the cost-effectiveness of the integrated strategy. The ability for ED and surgeon leadership to agree to adopt the integrated strategy is critical for the integrated strategy to deliver the effectiveness demonstrated herein.

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