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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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http://dx.doi.org/10.1016/j.jval.2015.10.007

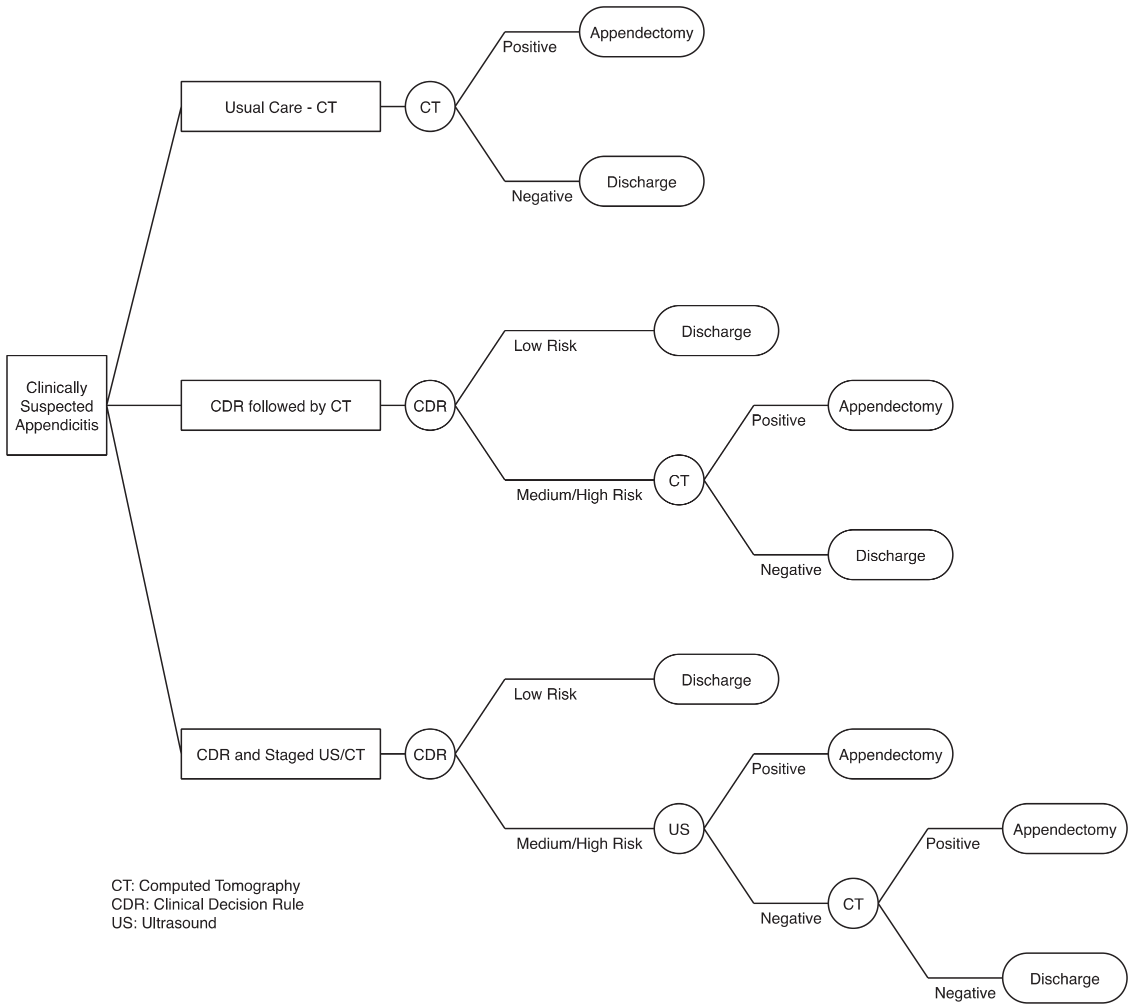

Fig. 1 – Decision tree of short-term events in the model. CDR, clinical decision rule; CT, computed tomography; US, ultrasound.

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