Journal of Pediatric Surgery 52 (2017) 1471–1474

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Cost comparison of initial lobectomy versus fine-needle aspiration for diagnostic workup of thyroid nodules in children☆

Katherine J. Baxter [a], Heather L. Short [a], Mitali A. Thakore [b], Jeremy G. Fisher [a], David H. Rothstein [c], Kurt F. Heiss [a], Mehul V. Raval [a,*]

[a] Division of Pediatric Surgery, Department of Surgery, Emory University School of Medicine Children's Healthcare of Atlanta, Atlanta, GA, United States
[b] Rollins School of Public Health, Emory University, Atlanta, GA, United States
[c] Department of Pediatric Surgery, Women and Children's Hospital of Buffalo; Department of Surgery, University at Buffalo, State University of New York, Buffalo, NY, USA

ARTICLE INFO

Article history:
Received 15 September 2016
Received in revised form 13 December 2016
Accepted 26 December 2016

Abbreviations:
FNA, fine-needle aspiration
DL, diagnostic lobectomy
US, ultrasound
ATA, American Thyroid Association
AUS, atypia of unknown significance
FLUS, follicular lesion of undetermined significance

ABSTRACT

Background: Though uncommon in children, pediatric thyroid nodules carry a higher risk of malignancy than adult nodules. While fine-needle aspiration (FNA) has been well established as the initial diagnostic test in adults, it has been more slowly adopted in children. The purpose of this study was to examine the comparative cost of FNA versus initial diagnostic lobectomy (DL) in the pediatric patient with an ultrasound-confirmed thyroid nodule.
Methods: A decision tree model was created using an adolescent with an asymptomatic thyroid nodule as the reference case. Probabilities were defined based on review of the pediatric and adult literature. Costs were determined from previous literature and the publicly available Medicare physician fee schedule. Tornado plot and sensitivity analyses were performed to assess sources of cost variation.
Results: Using decision analysis, FNA was less costly than DL with an estimated cost of $2529 vs. $5680. Tornado analysis demonstrated that the probability of an initial indeterminate FNA result contributed most to cost variation. On sensitivity analysis, when probability of an indeterminate FNA result was increased to 35%, the maximum value found in the literature, FNA remained less costly. In Monte Carlo simulation set to 10,000 iterations, FNA was superior to DL in 74% of cases.
Conclusions: In this theoretical model based on available literature and costs, FNA is less costly than DL for initial diagnostic workup of thyroid nodules in children. Securing resources to offer FNA in the work-up of thyroid nodules may be financially beneficial to hospitals and patients.
Level of evidence: Level 1 cost effectiveness study - using reasonable costs and alternatives used in study with values obtained from many studies, study used multi-way sensitivity analysis.

Although thyroid nodules are uncommon in children and adolescents, approximately 26% of thyroid nodules are malignant in children compared to 5% in adults [1]. Nevertheless, the majority of pediatric thyroid nodules are benign and represent a wide differential beyond malignancy including follicular adenoma, colloid cysts, nodular thyroiditis, and abscess. While in the past diagnostic lobectomy (DL) was the primary diagnostic modality for thyroid nodules, fine-needle aspiration (FNA) has emerged over the last three decades as a safe and accurate test which can obviate the need for operation in many patients [2,3].

In combination with thyroid ultrasound (US), FNA has been widely accepted as the initial diagnostic study of choice in adult thyroid nodules. Because of lingering concerns over risk of complications, need for anesthesia, non-diagnostic specimens, and reduced accuracy in children, adoption of FNA in the pediatric population has been slower [4–6]. Multiple studies have assessed the safety and diagnostic accuracy of FNA in the pediatric population, and a recent meta-analysis of 12 studies showed robust sensitivity and specificity for malignancy, similar to adult populations [7–9]. The 2015 update of pediatric thyroid nodule guidelines from the American Thyroid Association (ATA) recommends management similar to adults with ultrasound-guided FNA as the initial diagnostic study [10].

Another barrier to the implementation of thyroid FNA in children is the need to mobilize complex resources, including specialists across multiple departments, in order to provide this service for a relatively small number of patients. Use of FNA has been shown to increase cost-effectiveness in adult populations, primarily by avoiding more costly surgery with subsequent hospital stay and potential

Abbreviations: FNA, fine-needle aspiration; DL, diagnostic lobectomy; US, ultrasound; ATA, American Thyroid Association; AUS, atypia of unknown significance; FLUS, follicular lesion of undetermined significance.

☆ Declaration of interest: The authors have no conflicts of interest to declare.

* Corresponding author at: Division of Pediatric Surgery, Department of Surgery, Emory University School of Medicine, Children's Healthcare of Atlanta, 1405 Clifton Road NE, Atlanta, GA 30322. Tel.: +1 404 785 0781; fax: +1 404 785 0800.
E-mail address: mehulvraval@emory.edu (M.V. Raval).

http://dx.doi.org/10.1016/j.jpedsurg.2016.12.021
0022-3468/

complications [11,12]. We hypothesized that an initial diagnostic strategy of FNA in a child with a thyroid nodule, in addition to improving patient care by meeting current guidelines, would confer significant cost savings over DL. If true, this information may help assuage concerns over the initial expense and effort of establishing a pediatric FNA program. The purpose of this study was to utilize a theoretical decision analysis framework that incorporates probabilities and cost estimates from pediatric literature whenever possible to determine if FNA is less costly than initial DL in children with a thyroid nodule.

1. Methods

1.1. Reference case

We developed a reference case scenario for our decision tree analysis. Given the greater incidence of thyroid cancer among adolescents as compared to younger children and females compared to males, we selected a 14-year-old female with a 1.0-cm thyroid nodule confirmed on ultrasound requiring tissue sampling for diagnosis. The patient has no comorbid or preexisting conditions and is otherwise asymptomatic. The time horizon for the case is one year.

1.2. Decision model

Fig. 1 displays a decision tree diagram created using TreeAge Pro 2009 (Williamstown, Massachusetts). Two pathways were established for diagnostic possibilities. The first option was a diagnostic lobectomy (DL). After the procedure, it was assumed that the issue was either resolved (benign pathology), or that the patient was referred for a completion lobectomy (malignant pathology).

The second diagnostic option was ultrasound-guided fine-needle aspiration (FNA). The categories established by the Bethesda System for Reporting Thyroid Cytopathology results were collapsed into the following categories (1) benign (BII) (2) indeterminate including non-diagnostic and AUS/FLUS (BI and BIII), and (3) malignant including follicular neoplasms and nodules suspicious for malignancy (BIV-BVI) [13]. We assume that benign nodules require no further action. Malignant nodules were classified as either follicular or cancerous. Follicular nodules were treated with DL first, followed by a completion thyroidectomy, if found to be cancerous on final pathology. Cancerous nodules were treated with total thyroidectomy. Nodules classified as AUS or FLUS were assumed to undergo repeat FNA. The results of the repeat FNA were classified as (1) malignant, (2) indeterminate, or (3) benign categories. The benign and malignant nodules were treated as described above. Indeterminate nodules were first resected with DL, followed by completion thyroidectomy, if necessary.

1.3. Probabilities

The range of probabilities for each decision point was determined by examining previous literature (Table 1). This was not a systematic literature review, but instead PubMed was searched using the terms *pediatric thyroid fine needle aspiration* and *thyroid fine needle aspiration cost effectiveness*. Several sources were also found by cross-referencing from the initially identified relevant articles. Specific point estimates were determined based on clinical judgment and approximating the median value from collected literature. We favored estimates from pediatric studies and from studies with a larger number of subjects where other factors were equal. We assume that clinical decisions will be made on the basis of the results of the method of diagnosis. Sensitivity analyses were performed using the full range of probabilities in multiple analyses as is standard within decision analysis methodology. Sensitivity analyses allow decision nodes to be varied to account for uncertain probabilities and outcomes.

1.4. Costs

All costs were obtained from existing literature and from the Medicare Physician Fee Schedule 2015B [11,14]. Non-facility limiting charges were used for Centers for Medicare & Medicaid Services (CMS) estimates to reflect the maximum charge a hospital may apply to each procedure. All costs derived from literature were adjusted for inflation to 2015 dollars using Bureau of Labor Statistics estimates (Table 2). Costs accounted for direct costs to the hospital associated with each procedure. Discounting was not accounted for within this analysis.

1.5. Statistical analysis

All analyses were conducted using decision analysis software. First, expected values for nodes were identified through rollback analysis. The decision tree was first analyzed using static probabilities to ascertain the preferred pathway for static values. Second, a tornado diagram was used to identify which variables contributed uncertainty to the model. Third, one-way sensitivity analysis was conducted on the probability of having an indeterminate initial FNA.

Finally, a Monte Carlo sensitivity analysis was performed. Monte Carlo simulation utilizes aggregate values from a sample of randomly generated independent events to predict real events. This analysis assumes that the probability of each event can be reasonably determined. Each probability was assumed to be a linearly distributed variable and each outcome as a normally distributed variable. Mean costs were used as utilities. The Monte Carlo simulation was set to 10,000 iterations.

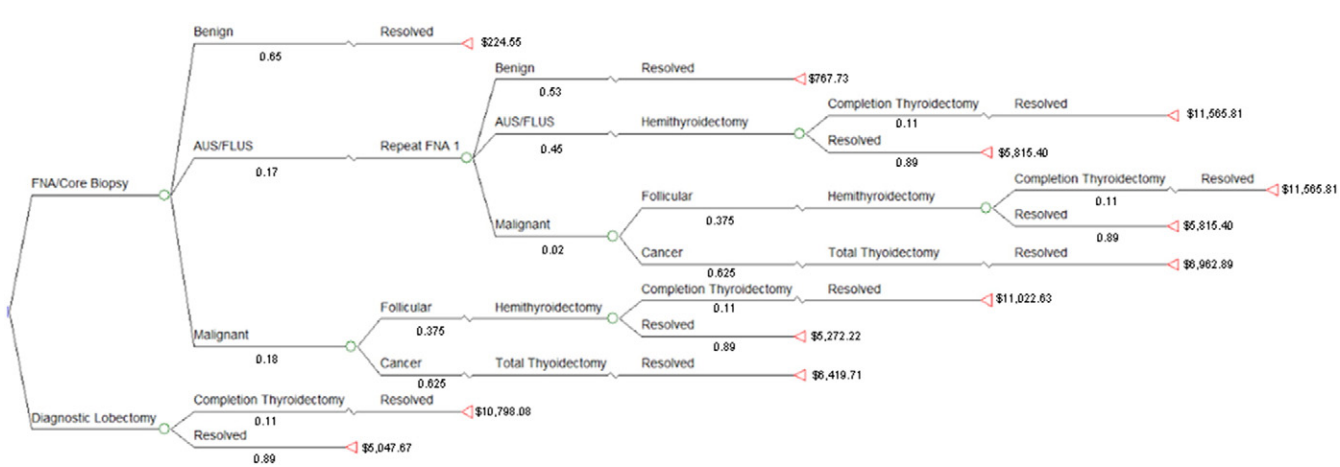

Fig. 1. Decision tree modeling costs of initial fine-needle aspiration (FNA) biopsy vs. diagnostic lobectomy (DL) for a pediatric patient with an ultrasound-confirmed thyroid nodule. Each circle represents a decision node and each triangle represents an end node. Probabilities (p) shown at applicable nodes.