

## Original Article

## The Cost of Penicillin Allergy Evaluation

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**What is already known about this topic?** Unverified penicillin allergy leads to adverse clinical and economic consequences. Penicillin allergy evaluation is a simple procedure, typically performed by allergy specialists. Time-driven activity-based costing (TDABC) is an accurate method to estimate the cost.

**What does this article add to our knowledge?** Using TDABC, we identified that penicillin allergy evaluation costs \$220 in the base case. In various univariable and multivariable sensitivity analyses, we identified a cost range of \$40 to \$537 for penicillin allergy evaluation.

**How does this study impact current management guidelines?** Penicillin allergy evaluation is inexpensive, even when considering operational challenges, such as infrequent or expanded testing. TDABC estimates of penicillin allergy evaluation can inform efficient clinical operations, the practice of cost-conscious care, and cost-effectiveness assessments.

**BACKGROUND:** Unverified penicillin allergy leads to adverse downstream clinical and economic sequelae. Penicillin allergy evaluation can be used to identify true, IgE-mediated allergy. **OBJECTIVE:** To estimate the cost of penicillin allergy evaluation using time-driven activity-based costing (TDABC). **METHODS:** We implemented TDABC throughout the care pathway for 30 outpatients presenting for penicillin allergy evaluation. The base-case evaluation included penicillin skin testing and a 1-step amoxicillin drug challenge, performed by an allergist. We varied assumptions about the provider type, clinical setting, procedure type, and personnel timing.

**RESULTS:** The base-case penicillin allergy evaluation costs \$220 in 2016 US dollars: \$98 for personnel, \$119 for consumables, and \$3 for space. In sensitivity analyses, lower cost estimates were achieved when only a drug challenge was performed (ie, no skin test, \$84) and a nurse practitioner provider was used (\$170). Adjusting for the probability of anaphylaxis did not result in a changed estimate (\$220); although other analyses led to modest changes in the TDABC estimate (\$214–\$246), higher estimates were identified with changing to a low-demand practice setting (\$268), a 50% increase in personnel times (\$269), and including clinician documentation time (\$288). In a least/most costly scenario analyses, the lowest TDABC estimate was \$40 and the highest was \$537.

**CONCLUSIONS:** Using TDABC, penicillin allergy evaluation costs \$220; even with varied assumptions adjusting for operational challenges, clinical setting, and expanded testing, penicillin allergy evaluation still costs only about \$540. This modest investment may be offset for patients treated with costly alternative antibiotics that also may result in adverse consequences. © 2017 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2017;■:■–■)

**Key words:** Hypersensitivity; Allergy; Beta-lactam; Resource; Skin test; Test dose; Challenge

Ten percent of the US population reports an allergy to penicillin antibiotics.<sup>1,2</sup> However, most patients with reported penicillin allergy are determined not to be allergic after an allergy evaluation.<sup>2–4</sup> Unverified penicillin allergy results in patients receiving broader-spectrum antibiotics, as well as antibiotics that may be more toxic, less effective, and/or higher cost.<sup>5,6</sup> Furthermore, unnecessary use of  $\beta$ -lactam alternative antibiotics places patients at risk for adverse reactions, treatment failures, and health care-associated infections.<sup>6–8</sup>

For patients with self-reported immediate (ie, IgE-mediated) penicillin allergy histories, penicillin skin testing and/or drug challenges under medical observation can accurately distinguish

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**Abbreviations used**

CCR- cost to charge ratio  
 CPT- Current Procedural Terminology  
 E&M- evaluation and management  
 MGH- Massachusetts General Hospital  
 RCC- ratio of costs to charges  
 RVU- relative value unit  
 TDABC- time-driven activity-based costing  
 USD- US dollars

true allergy. Currently, most penicillin skin testing in the United States is performed using major determinant, or benzylpenicilloyl (PRE-PEN, ALK-Abelló, Hørsholm, Denmark), and dilutions of penicillin G. The negative predictive value of penicillin skin testing using these reagents is at least 95%.<sup>2</sup> Allergists may additionally skin test with ampicillin because side-chain-specific allergy to aminopenicillins has been documented.<sup>9,10</sup> Most practices follow a negative penicillin skin test result with an observed test dose challenge to amoxicillin, which increases the negative predictive value of the evaluation to almost 100%.<sup>11</sup>

Although penicillin allergy evaluation has been hypothesized to be a cost-effective intervention,<sup>6</sup> there have been no costing studies or cost-effectiveness analyses of penicillin allergy evaluation in patients with reported penicillin allergy. Time-driven activity-based costing (TDABC), a method developed by health care economists, estimates cost through the calculation of both time spent using a given resource and the per-unit cost of such resource.<sup>12,13</sup> Since its development, TDABC has been used effectively in health care settings to determine cost and identify value in oncology,<sup>14</sup> urology,<sup>15</sup> interventional radiology,<sup>16</sup> and surgery.<sup>17-22</sup>

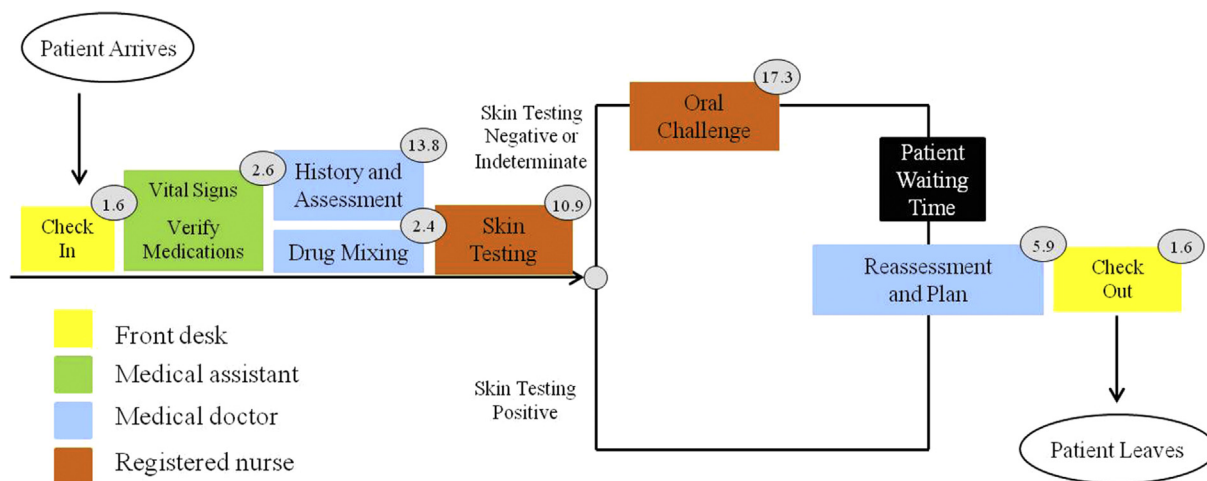
To inform efficient clinical operations, encourage cost-conscious care, and enable cost-effectiveness research, we performed TDABC of penicillin allergy evaluation. We additionally compared TDABC estimates to estimates derived from 2 other common costing

models: (1) the ratio of costs to charges (RCC) method and (2) the relative value unit (RVU) method.<sup>12,13,23</sup>

**METHODS****The TDABC method**

**Base case.** We considered the base case of an outpatient penicillin allergy visit with an American Board of Allergy and Immunology-certified Allergist/Immunologist who, after taking the allergy history, ordered skin testing with major determinant and dilutions of penicillin G, as well as a 1-step amoxicillin 500 mg oral challenge for all patients whose skin test result was negative. To estimate the cost of the base case, we defined each step along the outpatient penicillin allergy evaluation pathway in a process map (Figure 1). We then identified the personnel, consumables, and space used for 30 unique patients presenting for penicillin allergy evaluation, a convenience sample of prospectively observed patients at Massachusetts General Hospital (MGH) Allergy Associates (Boston, Mass). Prior to their visit, the patients were deemed appropriate for a penicillin allergy evaluation appointment. Tested patients had immunologic reactions that were potentially IgE-mediated, but not anaphylactic in the last 5 years. We determined that 30 patients provided sufficiently stable time estimates by assessing personnel and space time descriptive characteristics (eg, means and SDs) for the first 25 patients compared with the final 5 patients. No significant time differences were observed, and the 30 patients comprised the sample.

We calculated capacity cost rates for each personnel type in 2016 US dollars (USD) per minute using regional and national compensation data that included salary, payroll taxes, and fringe benefits (eg, health insurance).<sup>24-26</sup> Regional and national averages, rather than actual MGH Allergy Associates compensation, were used to achieve more generalizable results. Allergists/Immunologists and other personnel were estimated to work 8.0 hours per day.<sup>27</sup> Within each work day, we assumed 5% idle or break time for physicians and 10% idle or break time for other personnel.<sup>12,27</sup> Twenty-one days of vacation, 6 days for educational time and sick/personal leave, and



**FIGURE 1.** Outpatient penicillin allergy evaluation process map. The process map identifies all components of outpatient penicillin allergy evaluation including personnel type (indicated by color). The numbers in the gray circles indicate the mean measured time (in minutes) for each process for the 30 prospectively observed outpatients at MGH's Allergy Associates. Note that patient time is excluded from the process map, given that costing is performed from the health care system perspective. Patient time spent in the clinical examination room and the test room is included in space cost (Table III).

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