

Diagnostic evaluation of inhalant allergies: A cost-effectiveness analysis

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ABSTRACT

Background: The purpose of this study was to compare the cost-effectiveness of modified quantitative testing (MQT), intradermal dilutional testing (IDT), and *in vitro* allergy testing as diagnostic methods used in the management of patients with suspected IgE-mediated inhalant allergies.

Methods: A systematic review was conducted to determine key statistics for analysis, such as prevalence of disease, and sensitivity and specificity of each diagnostic modality. Costs were calculated based on charges from distribution companies to providers. A deterministic cost-effectiveness analysis then was conducted using a decision tree model to evaluate the various diagnostic strategies. After identifying results at baseline, we performed a sensitivity and threshold analysis to assess the strength of recommendations.

Results: At an allergic rhinitis prevalence of 20%, MQT dominated IDT and *in vitro* testing, with 85 people correctly diagnosed at a baseline total cost of \$6630 for the 100 patients tested. Although *in vitro* testing had the highest effectiveness, it had an incremental cost-effectiveness ratio of \$3185. The results were sensitive to changes in the prevalence, costs, and sensitivities and specificities of the different modalities.

Conclusion: The prevalence of allergic rhinitis is high and rising according to many studies, leading to a growing population of patients requiring allergy testing. Not only does today's medical community want effective health interventions, but also there is pressure to make health care cost efficient. This study looks at the cost-effectiveness of various diagnostic allergy tests. In our model, we found MQT to be the most cost-effective method of diagnosing allergic disease.

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Key words: Allergic rhinitis, allergy diagnosis, allergy testing, cost-effectiveness, *in vitro* allergy testing, MQT, skin testing

In a cross-sectional analysis of 1500 eighth graders, Mortz *et al.* estimated the lifetime prevalence of inhalant allergy at 17.7%.¹ Others have estimated the lifetime prevalence to be between 24 and 28%. Allergic diseases are some of the most common medical problems encountered in outpatient settings. The management of rhinitis accounts for nearly 3% of all physician visits, with the incidence of allergies in many otolaryngology practices around 50%. In addition to the visits and complications that allergic rhinitis has by itself, there are many conditions complicated by allergic rhinitis.^{2–5} If untreated or undertreated, the number of doctor visits and related costs, as well as decreased quality of life, diminished job performance, and missed work or school, can lead to a substantial economic burden. In 1996, a total direct cost of \$5.9 billion for allergic rhinitis was reported.⁶ In 1998 it was estimated that the days lost from work and decreased productivity cost US businesses >\$250 million.⁷

Because of the significant economic impact of allergic rhinitis, it is important that it is diagnosed and treated correctly. The American Academy of Allergy, Asthma, and Immunology defines allergy as “an acquired potential to develop immunologically mediated adverse reactions to normally innocuous substances upon re-exposure to the sensitizing allergen (including IgE antibody responses to allergens), causing the release of inflammatory mediators.”⁸ Recognition of allergy

patients requires an adequate history and physical examination.⁹ The diagnosis of allergic rhinitis actually requires three factors: (1) positive history, (2) demonstration of IgE-mediated potential to inhalant allergens by *in vitro* or *in vivo* testing, and (3) correlation between testing and history.^{10,11}

There are several types of tests available to identify specific allergies for effective immunotherapy. These are generally broken into two major categories: *in vitro* and *in vivo* testing. *In vivo* tests consist of skin-testing techniques. The options include scratch testing, skin-prick testing (SPT), and intradermal testing (IDT). In SPT, an assay of allergens is applied to the skin through a scratch or prick technique. There is a positive (histamine) and a negative (saline) control. A wheal 3 mm greater in diameter than the negative control reaction reflects the presence of mast cell-bound IgE specific to the tested allergen. IDT is more sensitive because the tested allergen is more diluted, but they have a lower specificity. IDT is performed by injecting 0.02 mL of a dilute allergen solution into the dermis. As with epicutaneous testing, the skin is observed for a wheal and flare reaction.^{11–13}

In vitro allergy testing, historically referred to as radioallergen sorbent testing, measures the concentration of allergen-specific IgE in the patient's serum. This test involves adding the patient's serum to a solid phase (usually a disk) coated with the allergen to be tested. Antibodies in the patient's serum specific for the allergen will bind to the solid phase. Although *in vitro* allergy testing results generally correlate with allergic sensitivity, it is more likely than skin testing to produce false negatives. As such, the sensitivity of *in vitro* testing is lower than that of skin testing.^{11,12}

Because insurance companies may or may not cover certain diagnostic testing methodologies, may vary greatly the

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amount reimbursed, and may limit the type or number of antigens tested, the decision was made to evaluate the economic impact of three allergy testing methods. The evidence of improved diagnostic advantage and resulting patient outcome is necessary before deciding the most appropriate diagnostic strategy. The objective of this study is to compare the cost-effectiveness, from the provider perspective, of allergy testing in the diagnosis and management of allergic rhinitis with the primary outcome measure being expected effectiveness and the incremental cost per additional correct diagnosis.

MATERIALS AND METHODS

Decision Model

A decision tree was constructed to study the cost-effectiveness of the three diagnostic strategies in 100 patients with clinical signs and symptoms of allergic rhinitis (Fig. 1). We examined this model to determine the short-term cost-effectiveness of three commonly used strategies: (1) modified quantitative testing (MQT), (2) IDT, and 3) *in vitro* allergy testing compared with no diagnostic testing.

To design our decision tree, we had to make several assumptions as listed in Table 1. It is also important to note that we assumed that all patients were being tested for the purpose of evaluation for immunotherapy. Therefore, we chose to look at costs of MQT over SPT. Quantitative testing offers the advantage of initiating immunotherapy with a higher antigen concentration. Studies show that initiating immunotherapy with a strong starting dose creates health care savings. There also is a good agreement between an antigen testing positive by SPT and the determination of a definable end point. Seshul *et al.* quote a correlation of 93%.¹⁴ we will assume a correlation of 100% for the purpose of the study (Table 1). In our sensitivity analysis the maximum sensitivity and specificity of all three diagnostic tests was assumed to approach 99%.

Data Sources

The values of the variables in the model, the range of sensitivities and specificities, and the data sources are listed in Table 2. Where available, we used the parameters set forth by the American Academy of Allergy, Asthma, and Immunology, as well as, the American Academy of Otolaryngic Al-

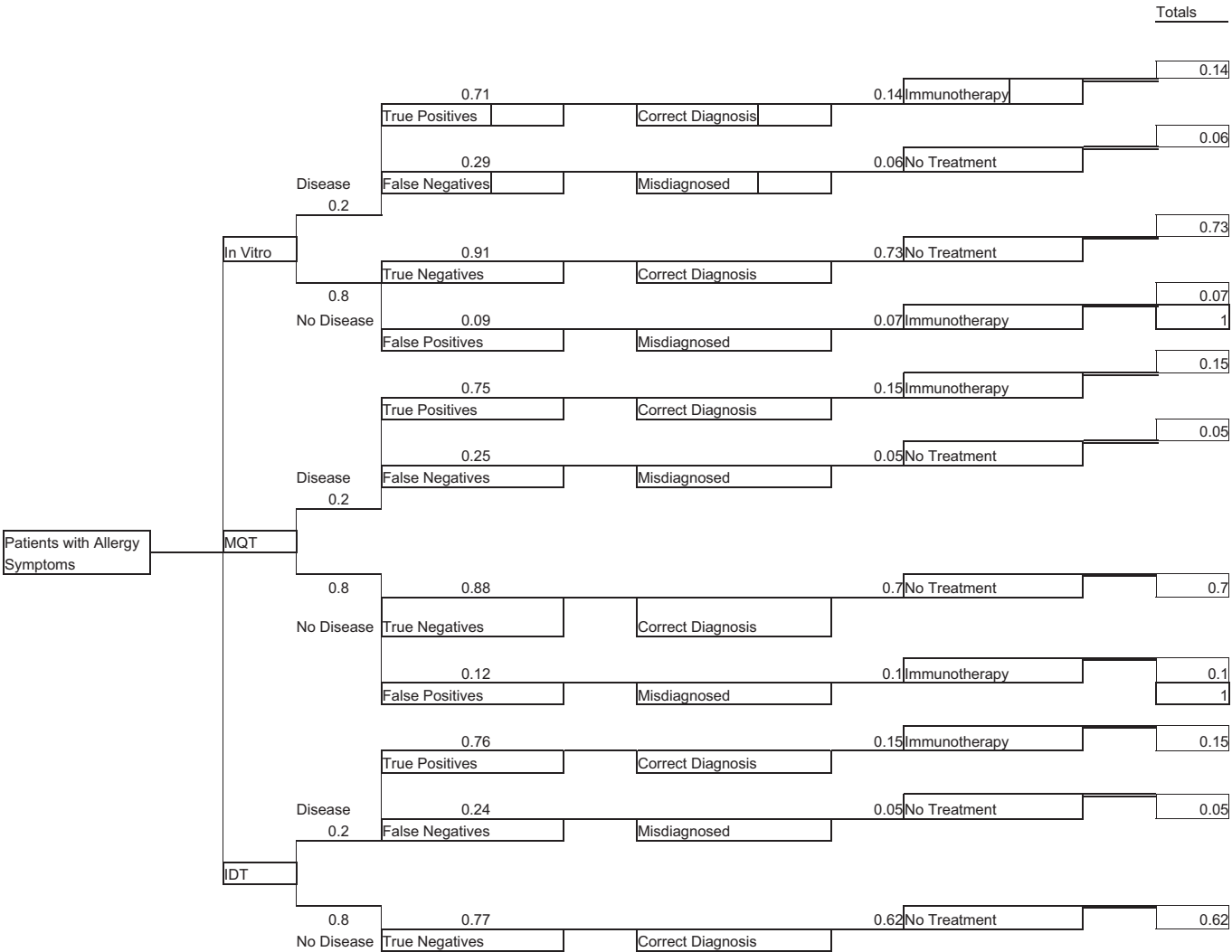


Figure 1. Decision tree evaluation of the diagnostic testing of inhalant allergies

Table 1 Baseline case scenario assumptions for decision tree

Construction
One hundred hypothetical patients with complaints fitting AAAAI guidelines for the diagnosis of allergic rhinitis without coexisting comorbidities or on any medications that would affect testing (Ref. 3)
One hundred percent agreement between an antigen testing positive by SPT and the determination of a definable end point
Serum for <i>in vitro</i> tests were sent to off-site laboratory
All tests performed according to current standard guidelines (Ref. 20)
One hundred percent patient compliance
The maximum sensitivity and specificity for diagnostic allergy tests approaches 99%
AAAAI = American Academy of Allergy, Asthma, and Immunology, Ref. 32.

lergy to set the sensitivities and specificities of diagnostic tests and utilities. Where the parameters were not clear, we used the results of a meta-analysis. Fixed costs were compiled from the major laboratories currently distributing testing supplies throughout the United States.

Variable costs were calculated based on the socioeconomic facts and figures published in the American Academy of Otolaryngology–Head and Neck Surgery 8th Annual Survey.¹⁵ Variable costs included physician labor costs to administer and grade the tests. Because venipuncture was not done in a clinic and we assumed *in vitro* allergy tests were sent to an outside laboratory, there were no variable costs calculated for this test. Also, because we are looking at the provider, specifically physician, costs, we did not include the time needed to prepare the tests or the room.

Prevalence

The overall prevalence of allergic rhinitis in the United States is estimated to be anywhere from 14 to 28% of the adult

population.^{2,4} To be consistent with most studies, we used a baseline estimate of 20%.¹⁶

Diagnostic Tests

Modified Quantitative Testing. We modeled a test in which patients were tested for 14 allergens and 2 controls by using the Multi-Test II (Antigen Laboratories, Inc., Liberty, MO). Two devices would be used to administer tests. We assumed our test was based on a standard procedure where a wheal 3 mm greater than our negative control was considered a positive test. To confirm our initial test and further quantify our response and for the purpose of immunotherapy starting doses, an intradermal test followed. If our initial response was between 3 and 8 mm, we used .03 mL of a number 3 concentrate. If our initial response wheal was >8 mm, we used a number 5 concentrate. Because of studies showing that positive intradermal responses after negative prick testing commonly occur, many test all negative pricks with a single IDT. Because, even when clinically correlated, the significance of these findings is uncertain, we did not test negative pricks and assumed a 100% correlation.^{17–19}

Intradermal Testing. We assumed standard testing²⁰ where there are a total of six vials of concentrate for each allergen. We assumed we started with a 1:5 concentrate in vial 1. For comparative purposes we tested a total of 14 allergens with 2 controls. As outlined in the current strategies for skin testing by Krouse and Mabry,²⁰ the classic method for intradermal dilutional testing starts with a number 6 concentrate. In other situations, such as during allergy season, when testing a brittle patient, or when a less-experienced person is administering the test, one should also begin with a number 6 concentrate. In favoring the side of conservatism, we started our testing with concentrate 6.²⁰

In Vitro Testing. We assumed we were testing each patient with the basic 15-allergen panel quoted in company product information. Because we have no on-site laboratory for *in vitro* testing, we modeled our test after our own clinical experience where venipuncture is performed at an on-site laboratory and serum is sent to a reference laboratory. Therefore, we included the cost of venipuncture and transporting specimens.

Table 2 Parameters used in decision tree analysis*

Parameter	Baseline Value	Range	Source
Cost of MQT	66.30	33.15–132.60	N/A
Cost of IDT	112.00	56.00–224.00	N/A
Cost of IVT	130.00	65.00–260.00	N/A
Sensitivity of MQT	75	57–97	Refs. 18, 22, 23, 24, and 25
Specificity of MQT	88	70–96	Refs. 22, 23, 24, and 25
Sensitivity of IDT	76	60–81	Refs. 22 and 23
Specificity of IDT	77	32–84	Refs. 22 and 23
Sensitivity of IVT	71	50–90	Refs. 22 and 25
Specificity of IVT	91	85–98	Refs. 22 and 25

*Costs are in U.S. dollars. Other values are expressed in percentages.

IVT = *in vitro* testing.

Table 3 Comparison of fixed costs

	Costs		
	MQT	IDT	IVT
Treatment wells	0.03		
Vial tray		0.04	
Cost of extract	0.48	0.96	
Controls*		0.28	
Device costs	3.60		
Other supplies			
Syringes	0.12	3.60	
Vials	0.07	1.12	
Panel			112.00
Venipuncture			16.00
Transportation			2.00
Total	4.30	6.00	130.00

*Control costs were not calculated separately in MQT testing since their average cost is the same as the extract cost.

Cost-Effectiveness Analysis

The incremental cost-effectiveness ratio (ICER) for the use of MQT, IDT, and *in vitro* testing in the diagnosis of allergic disease is

$$\text{ICER} = (\text{CA} - \text{CB})/(\text{EA} - \text{EB})$$

where C and E are the expected cost and effectiveness, respectively, of testing strategies A and B. Thus, the ICER tells how much in additional costs must be incurred to achieve one additional correct diagnosis if the most effective test is used. If the cost-effectiveness ratio is a negative number, it shows that the study not only costs more, but also is less effective.

Sensitivity Analysis

In a one-way sensitivity analyses, we varied all probabilities by varying one model variable at a time to determine whether the results were sensitive to our estimated values for the cost and sensitivities and specificities of MQT, IDT, and *in vitro* testing. We also determined threshold values for the prevalence of allergic rhinitis. Our ranges of variables can be seen in Table 2.

RESULTS

Fixed costs were calculated according to the costs of materials from major allergy supply laboratories. For multitesting purposes, the cost of extract for 16 skin tests, 2 multitest devices, the multiwell, and the syringes were estimated also

Table 4 Total cost difference between tests

	MQT	IDT	IVT
Fixed costs	4.30	6.00	130.00
Variable costs	62.00	106.00	
Total costs	66.30	112.00	130.00

(see Table 3).²¹ Total cost for one round of MQT testing costs an estimated \$4.30.

To perform IDT, the costs of the plastic vial tray, saline vials, and syringes were considered. According to our calculations, to make a testing tray for serial dilutions for 14 allergens with concentration vials 6–1 and 2 controls cost a total of \$159.02.¹³ Total fixed cost per test is estimated at \$6.00, slightly less than the cost for MQT. We did not vary our calculations based on which concentration was used because of the fact that clinical facilities do not make only one concentrate at a time. When one vial is empty, a complete new treatment tray must be made.

The cost of *in vitro* testing was calculated also, and, when considering only fixed costs, was found to be the most expensive test at \$130 (Table 3). Variable costs were based on the time it took physicians to administer and grade the MQT and IDT. In our clinic, the average time to perform MQT is 35 minutes and IDT is 1 hour. Based on the Facts and Figures from the 8th Annual Survey of Otolaryngologists published by the American Academy of Otolaryngology, the variable costs for performing MQT and IDT are \$106 and \$62, respectively.¹⁵ Total costs are shown in Table 4.

Using the average sensitivity and specificity found in the literature, the most effective test was the *in vitro* method with the most total correct diagnosis: 87 compared with 77 for IDT and 85 for MQT. Compared with MQT, however, the incremental cost for the two additional correct diagnoses was \$6370, averaging \$3185/additional correct diagnosis (Table 5). IDT costs more and had the least number of patients correctly diagnosed.

When performing our sensitivity analysis, we found results to be sensitive to changes in the prevalence, cost, and sensitivity and specificity (Table 6). At an increased cost of \$130/MQT test, the ICER for *in vitro* testing was reduced to \$0, meaning no additional charges per correct diagnosis. Similarly, reducing the cost of RAST to \$66.30/test also reduced the ICER to \$0. When the cost of IDT dropped below a threshold value of \$66.30, the cost per additional correct diagnosis obtained with MQT began to increase (Figs. 2–4).

Increasing the prevalence of disease decreased the number of patients correctly diagnosed using each test. When the prevalence was increased to a threshold value of 45%, MQT surpassed

Table 5 Cost-effective analysis

Algorithm	Correct Dx (E)	Total Charges \$ (C)	Additional Correct Dx	Additional Charges (\$)	ICER(\$)
IDT	77	11,200	77	11,200	145.45
MQT	85	6630	8	–4570	–571.25
IVT	87	13,000	2	6370	3185

Table 6 Sensitivity analysis

Assumption	Base	Min	Max	C/E (Base)	C/E (Min)	C/E (Max)
No gold standard						
MQT						
Sensitivity	0.75	0.57	0.99	\$ 77.63	\$ 81.05	\$ 73.50
Specificity	0.88	0.70	0.99	\$ 77.63	\$ 93.38	\$ 70.38
Cost	66.30	33.15	132.60	\$ 77.63	\$ 38.82	\$155.27
Prevalence	20%	10%	100%	\$ 77.63	\$ 76.47	\$ 88.40
IDT						
Sensitivity	0.76	0.60	0.99	\$145.83	\$152.17	\$137.59
Specificity	0.77	0.32	0.99	\$145.83	\$274.50	\$118.64
Cost	112.00	56.00	224.00	\$145.83	\$ 72.92	\$291.67
Prevalence	20%	10%	100%	\$145.83	\$145.64	\$147.37
IVT						
Sensitivity	0.71	0.50	0.99	\$149.43	\$157.60	\$140.39
Specificity	0.91	0.85	0.99	\$149.43	\$158.15	\$139.19
Cost	130.00	65.00	260.00	\$149.43	\$ 74.71	\$298.85
Prevalence	20%	10%	100%	\$149.43	\$146.07	\$183.10

Min = minimum; Max = maximum.

in vitro testing as the most effective test. Similarly, at prevalence >87%, IDT became the most effective test, with more patients correctly diagnosed than either of the other tests (Fig. 5).

At a threshold sensitivity of 83% or specificity of 90%, MQT became the most effective test. By separately decreasing the sensitivities and specificities of *in vitro* testing to threshold values of 63 and 89%, respectively, MQT surpassed *in vitro* allergy testing as the most effective test. Varying the sensitivity of IDT did not change its relative effectiveness; however, by increasing the specificity to $\geq 90\%$, IDT surpassed *in vitro* testing in cost-effectiveness. Compared with MQT, at a threshold specificity of 88%, IDT had similar effectiveness with a higher cost per correct diagnosis.

DISCUSSION

In the last 20 years, increasing importance has been placed on the use of economic evidence to support health policies. Cost-effectiveness studies are an important part of the economic evaluation process used to determine health

care guidelines.^{22,23} Methods of allergy testing have even been disputed by third party payers, with many refusing to pay for IDT.¹⁴ This study looks at the efficiency, as well as the cost-effectiveness of the three major types of allergy testing with the primary outcome being the ICER. The assumption is then made that the additional person will be correctly diagnosed and treated for a substantial cost. Because of the discrepancy between charges and payments from third party payers, we focused this study on provider costs.

When performing our initial literature review, we found IDT had the highest average sensitivity (76%) and *in vitro* testing had the highest average specificity (91%). For each test, however, there is a broad range of sensitivities and specificities quoted in the literature. When using baseline values, we found the MQT to be the most cost-effective test.

Our sensitivity analysis shows that these results can not be standardized to all laboratories. For clinics with baseline total

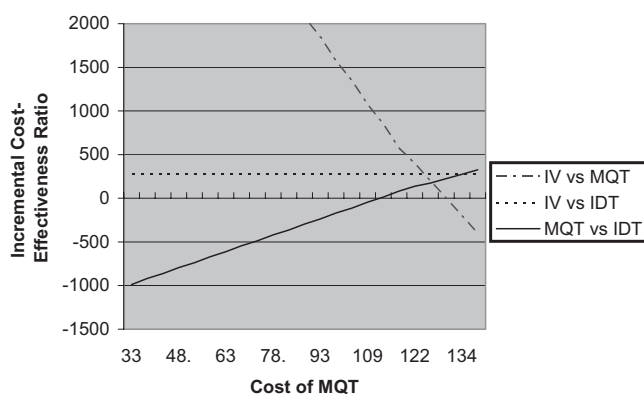


Figure 2. Sensitivity analysis varying the cost of MQT.

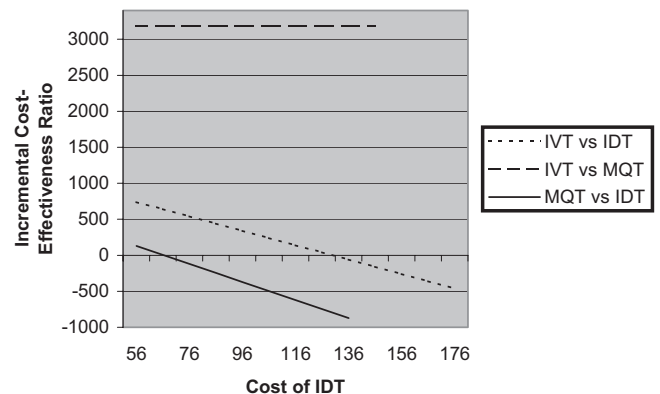


Figure 3. Sensitivity analysis varying the cost of IDT.

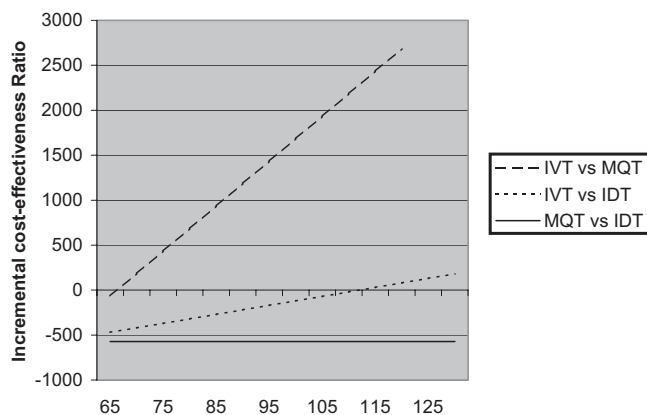


Figure 4. Sensitivity analysis varying the cost of radioallergosorbent test (RAST).

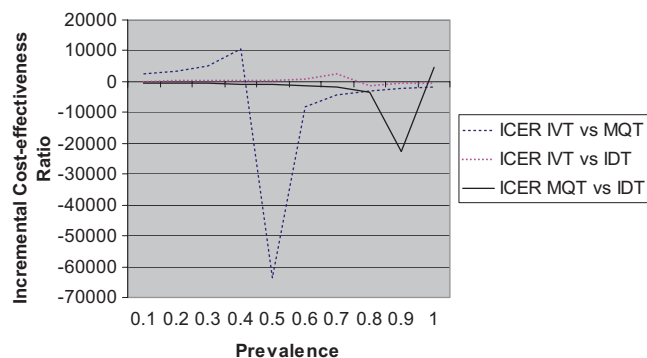


Figure 5. Sensitivity analysis varying the prevalence of disease.

costs for MQT >\$130, *in vitro* testing may be a better choice. In a laboratory showing a specificity of IDT >92%, this may be the best test choice. Also, in a community showing an extremely high prevalence, IDT becomes a more favorable choice.

It is important to note that there is a wide range of sensitivities and specificities listed in our sensitivity analysis.^{24–26} Part of the reason for this is because of the fact that there is “no gold standard in allergy testing.” The use of patient history is inadequate as a gold standard because the true clinical state is unknown. Many studies incorrectly use these terms resulting in tests with little clinical usefulness. To detect the true clinical state of the patient, Kemp and Lockey suggest the gold standard be based on an allergen challenge that simulates natural exposure. Although they do list a range of sensitivities and specificities in their review of diagnostic testing, they note that this is a “misnomer without knowledge of the true clinical state.” The accuracy of each of these tests also varies between laboratories, with operator error and standard technique often playing a significant role.^{27,28} For example, studies show that sensitivities vary between the different devices chosen for testing.^{29–31} In addition, if skin testing is performed infrequently in a particular laboratory, there may be a lot of wasted expenses on products and personnel making *in vitro* testing a more attractive option.

Other contingencies to this study include the fact that we did not follow up each negative SPT with IDT, which is

common in many practices. This would have significantly changed the cost and efficacy of our testing methods. When calculating the fixed costs of allergy testing, we may not have had the information for the wide range of materials and discounts available. We did not take into account the costs of training personnel. It is also important to remember that this is a statistical model and is therefore limited by its lack of clinical outcomes.

CONCLUSION

The prevalence of allergic rhinitis is high, and rising according to many studies, leading to a growing population of patients requiring allergy testing. Not only does today’s medical community want effective health interventions, but also there is pressure to make health care cost efficient. This study looks at the cost-effectiveness of various diagnostic allergy tests. In our model, we found MQT to be the most cost-effective method of diagnosing allergic disease.

REFERENCES

1. Mortz CG, Lauritsen JM, Bindsley-Jensen C, et al. Prevalence of atopic dermatitis, asthma, allergic rhinitis, and hand and contact dermatitis in adolescents. The Odense Adolescence Cohort Study on atopic diseases and Dermatitis. *Br J Dermatol* 144:523–532, 2001.
2. Scarupa M, and Kaliner M. Allergic Diseases Resource Center: Rhinitis. Available online at www.worldallergy.org/professional/allergic_diseases_center/rhinitis/rhinitis/in-dept; last accessed Nov. 7, 2006.
3. Dykewicz MS, Fineman S, Skoner DP, et al. Diagnosis and management of rhinitis: complete guidelines of the Joint Task Force on Practice Parameters in Allergy, Asthma and Immunology. American Academy of Allergy, Asthma and Immunology. *Ann Allergy Asthma Immunol* 81:478–518, 1998.
4. Linneberg A, Nielsen NH, Madsen F, et al. Increasing prevalence of specific IgE to aeroallergens in an adult population: Two cross-sectional surveys 8 years apart: The Copenhagen allergy Study. *J Allergy Clin Immunol* 106:247–252, 2000.
5. Hueston KC, Mabry RL, and Mabry CS. The importance of allergy in an ENT practice. In *Allergy in ENT Practice*, 2nd ed. New York: Thieme, 1998. 3–6.
6. Malone DC, Lawson KA, Smith DH, et al. A cost of illness study of allergic rhinitis in the United States. *J Allergy Clin Immunol* 99:22–27, 1997.
7. Hewitt Associates LLC. Allergy costs may cause watery eyes for employers. *Managing Health and Business Productivity*. Available online at www.was.hewitt.com/hewitt/business/healthmgt/subhealth/hlbus_allergies.htm; last accessed May 15, 2001.
8. The Allergy Report. Overview of Allergic Diseases: Diagnosis, Management, and Barriers to Care, Vol. 1–3. San Diego: American Academy of Allergy, Asthma, and Immunology (AAAAI), 2000.
9. Spector S, Nicklas RA, Chapman J, et al, for the Joint Task Force on Practice Parameters; American Academy of Allergy, Asthma, and Immunology; Joint Council of Allergy, Asthma, and Immunology. Symptom severity assessment of allergic rhinitis: Part 1. *Ann allergy Asthma Immunol* 91: 105–114, 2003.
10. Lang DM. Management of allergic rhinitis. *Geriatric Times* 3, 2002.

11. American College of Physicians. Allergy testing. *Ann Intern Med* 110:317–320, 1989.
12. Krouse JH, Chadwick SJ, Gordon BR, and Derebery MJ (eds.). *Skin testing in the diagnosis of inhalant allergy*. In *Allergy and Immunology: An Otolaryngic Approach*. New York: Lippincott Williams & Wilkins, 2002. 114–124.
13. Altman LC, Becker JW, and Williams PV (eds.). *Skin tests, in vitro tests*. In *Allergy in Primary Care*. Philadelphia: W.B. Saunders Co., 2000. 37–64.
14. Seshul M, Pillsbury, and Eby T. Use of intradermal dilutional testing and skin prick testing: Clinical relevance and cost efficiency. *Laryngology* 116:1530–1538, 2006.
15. American Academy of Otolaryngology–Head and Neck Surgery. Socioeconomic facts and figures, 8th Annual Survey. Alexandria, VA: AAO-HNF, 2004.
16. Nathan, RA, Meltzer EO, Selner JC, et al. Prevalence of allergic rhinitis in the United States. *J Allergy Asthma Immunol* 99:2808–2814, 1997.
17. Peltier J, and Ryan MW. Comparison of Intradermal dilutional testing with the multi-test II applicator in testing for mold allergy. *Otolaryngol Head Neck Surg* 134:240–244, 2006.
18. McKay SP, Mesleman D, Stachler RJ, and Krouse JH. Intradermal positivity after negative prick testing for inhalants. *Otolaryngol Head Neck Surg* 135:232–235, 2006.
19. Peltier J, and Ryan MW. Comparison of intradermal dilutional testing, skin prick testing, and modified quantitative testing for common allergens. *Otolaryngol Head Neck Surg* 137:246–249, 2007.
20. Krouse JH, and Mabry RL. Skin testing for inhalant allergy 2003: Current strategies. *Otolaryngol Head Neck Surg* 129: S33–S49, 2003.
21. Shal SB, and Emanuel EA. Cost analysis of employing multi-test allergy screening to guide serial endpoint titration (SET) testing versus SET alone. *Otolaryngol Head Neck Surg* 129: 1–6, 2003.
22. Drummond MF, and Jefferson. Guidelines for authors and peer reviewers of economic submissions to the BMJ. *BMJ* 313:275–288, 1996.
23. Gerard K, Seymour J, and Smoker I. A tool to improve quality of reporting published economic analyses. *Int J Tech Assess HC* 16:100–110, 2000.
24. Wood RA, Phipatanakul W, Hamilton RG, et al. A comparison of skin prick tests, Intradermal skin tests, and RASTs in the diagnosis of cat allergy. *J Allergy Clin Immunol* 103:1–10, 1999.
25. Takowoingi Y, Effiong A, Nwaorgu G, et al. Comparing nasal secretion eosinophil count with skin sensitivity test in allergic rhinitis in Ibadan, Nigeria. *Acta Otol* 123:1070–1074.21, 2003.
26. Bernstein IL, and Storms WW. Practice parameters for allergy diagnostic testing. Joint task force on practice parameters for the diagnosis and treatment of asthma. The American Academy of Allergy, Asthma, and Immunology. *Ann Allergy Asthma Immunol* 75:543–625, 1995.
27. Kemp SF, and Lockey RF (eds.). *Percutaneous and intracutaneous diagnostic tests of IgE-mediated diseases (immediate hypersensitivity)*. In *Diagnostic Testing of Allergic Disease*. New York: Marcel Dekker, Inc., 2000. 53–80.
28. Demoly P, Francois-Bernard M, and Bousquet J. In vivo methods for study of allergy skin tests, techniques, and interpretation. In *Allergy Principles and Practice*, 5th ed. Middleton E Jr, Reed CE, Ellis E, et al. (Eds). St. Louis: Mosby-Year Book, 430–439, 1998.
29. Nelson HS, Lahr J, Buchneier A, et al. Evaluation of devices for skin prick testing. *J Allergy Clin Immunol* 101:153–156, 1998.
30. Yoon IK, Martin BI, and Carr WW; The immunotherapy committee of the American Academy of Allergy, Asthma, and Immunology. A comparison of two single-headed and two multi-headed allergen skin test devices. *Allergy Asthma Proc* 27:473–478, 2006.
31. Carr WW. Improvements in skin-testing technique. *Allergy Asthma Proc* 27:100–103, 2006.
32. AAAAI. Guidelines to minimize the risk from systemic reactions caused by immunotherapy with allergenic extracts. AAAAI position statement #25. Available on-line at www.aaaai.org; last accessed April 2008. □

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