Cost-Effectiveness of Radiofrequency Ablation for Supraventricular Tachycardia

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Background: **Radiofrequency ablation is an established but expensive treatment option for many forms of supraventricular tachycardia. Most cases of supraventricular tachycardia are not life-threatening; the goal of therapy is therefore to improve the patient's quality of life.**

Objective: **To compare the cost-effectiveness of radiofrequency ablation with that of medical management of supraventricular tachycardia.**

Design: **Markov model.**

Data Sources: **Costs were estimated from a major academic hospital and the literature, and treatment efficacy was estimated from reports from clinical studies at major medical centers. Probabilities of clinical outcomes were estimated from the literature. To account for the effect of radiofrequency ablation on quality of life, assessments by patients who had undergone the procedure were used.**

Target Population: **Cohort of symptomatic patients who experienced 4.6 unscheduled visits per year to an emergency department or a physician's office while receiving long-term drug therapy for supraventricular tachycardia.**

Time Horizon: **Patient lifetime.**

Perspective: **Societal.**

Interventions: **Initial radiofrequency ablation, long-term antiarrhythmic drug therapy, and treatment of acute episodes of arrhythmia with antiarrhythmic drugs.**

Outcome Measures: **Costs, quality-adjusted life-years, life-years, and marginal cost-effectiveness ratios.**

Results of Base-Case Analysis: **Among patients who have monthly episodes of supraventricular tachycardia, radiofrequency ablation was the most effective and least expensive therapy and therefore dominated the drug therapy options. Radiofrequency ablation improved quality-adjusted life expectancy by 3.10 quality-adjusted life-years and reduced lifetime medical expenditures by $27 900 compared with long-term drug therapy. Long-term drug therapy was more effective and had lower costs than episodic drug therapy.**

Results of Sensitivity Analysis: **The findings were highly robust over substantial variations in assumptions about the efficacy and complication rate of radiofrequency ablation, including analyses in which the complication rate was tripled and efficacy was decreased substantially.**

Conclusions: **Radiofrequency ablation substantially improves quality of life and reduces costs when it is used to treat highly symptomatic patients. Although the benefit of radiofrequency ablation has not been studied in less symptomatic patients, a small improvement in quality of life is sufficient to give preference to radiofrequency ablation over drug therapy.**

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Supraventricular tachycardia affects approximately 570 000 people in the United States, and about 89 000 incident cases occur annually (1). Most cases of supraventricular tachycardia are caused by atrioventricular nodal reentrant tachycardia. Many of the other cases are due to reentrant conduction involving a bypass tract that forms a connection between the atrium and ventricle (2). With the exception of the Wolff–Parkinson–White syndrome, supraventricular tachycardia is rarely life-threatening. However, severely symptomatic patients have multiple episodes per year that require urgent medical intervention to terminate the arrhythmia; these episodes substantially diminish quality of life (3).

Radiofrequency ablation is an established treatment option for most forms of supraventricular tachycardia (2, 4–9). To perform radiofrequency ablation, a clinician uses a transvenous, steerable electrode catheter to deliver radiofrequency energy directly to the slow pathway of the atrioventricular node or to a bypass tract (6, 9). The radiofrequency energy heats the myocardial tissue, creating a lesion that interrupts conduction through a portion of the reentry circuit. In 1996, 18 000 catheter-ablation procedures were performed in the United States, three times the number of procedures in 1990 (10, 11). Radiofrequency ablation has a reported success rate of greater than 90% in leading centers (4, 6, 12–18). For highly symptomatic patients, radio-

frequency ablation can improve functional status compared with long-term drug therapy or episodic treatment of acute arrhythmias (19, 20). Although radiofrequency ablation is highly efficacious, the procedure both carries modest risk for complications and is relatively costly (21, 22).

Previous economic analyses of radiofrequency ablation generally have been favorable, but they have been limited because they compared radiofrequency ablation with therapies that are now obsolete (23); studied costs but not effectiveness (23–26); or evaluated radiofrequency ablation only for treatment of the Wolff–Parkinson–White syndrome (27), a potentially life-threatening form of supraventricular tachycardia. In addition, measures of the effect of radiofrequency ablation on quality of life (3) were not available when previous analyses were performed. Because successful radiofrequency ablation primarily improves quality of life rather than extending life, such measures are an essential component of a comprehensive evaluation of the cost-effectiveness of radiofrequency ablation (28).

We compared the cost-effectiveness of radiofrequency ablation with that of two strategies of drug therapy for patients with severely symptomatic supraventricular tachycardia due to atrioventricular nodal reentrant tachycardia or a concealed bypass tract. We excluded patients with the Wolff–Parkinson–White syndrome since the cost-effectiveness of radiofrequency ablation in these patients has been assessed (27).

METHODS

We used a decision model to compare the health and economic outcomes of three treatment strategies for patients with supraventricular tachycardia: initial radiofrequency ablation, long-term antiarrhythmic drug therapy, or treatment of acute episodes of arrhythmia with antiarrhythmic drugs (**Figure 1**). Taking a societal perspective, we calculated the marginal cost-effectiveness of these strategies, and we discounted both costs and benefits at an annual rate of 3% (28). We performed one-way sensitivity analyses on all the model variables, as well as selected two- and three-way sensitivity analyses, five-way sensitivity analyses, and *n*-way (Monte Carlo) probabilistic sensitivity analyses.

We based the estimates for input variables on the literature whenever possible (1–4, 6–8, 12–14, 16–18, 21–23, 26, 28–73) (**Table 1**). Our base-case estimates represent our judgment about the best estimate from the literature and discussion with experts. For clinical variables, our ranges for sensitivity analyses represent our judgment of the variation likely to be encountered in clinical practice, based on the literature and discussion with experts. The ranges for costs represent variation by 25% above and below the base-case estimate. The ranges for sensitivity analyses on quality-of-life estimates represent the 25th and 75th percentiles of patients' assessments of quality of life (3). When the literature was conflicting or inadequate, we consulted experts in the Cardiac Arrhythmia Patient Outcome Research Team Project and experts in electrophysiologic testing and radiofrequency ablation.

Decision Model

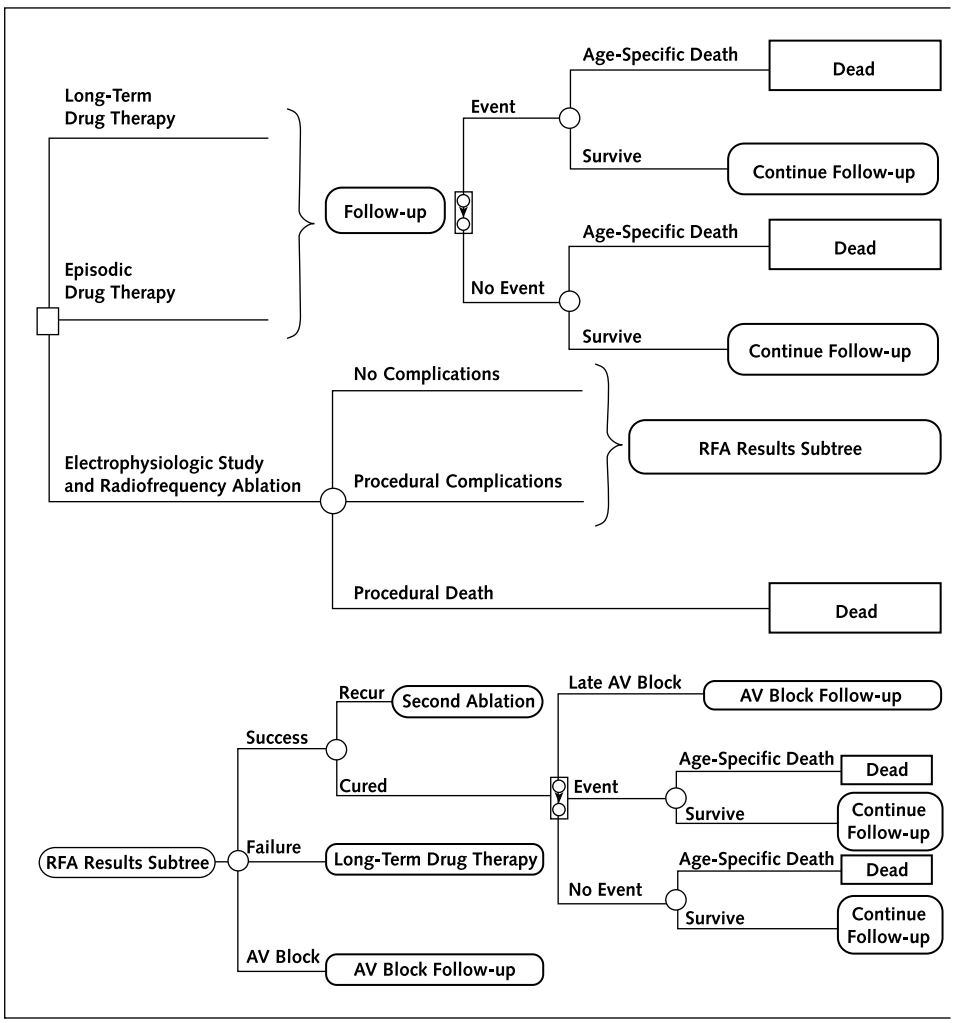
We used Decision Maker software (Pratt Medical Group, Boston, Massachusetts) to develop a Markov model (75). For each treatment strategy, our model included the major procedures, probability of various procedural complications, probability of death, costs, and quality of life associated with health outcomes. When possible, we based our probability estimates (**Table 1**) on large studies conducted at centers with substantial experience with radiofrequency ablation (13, 14, 16, 31, 32).

Our model (**Figure 1**) tracked a hypothetical cohort of patients who received one of the three treatment strategies. Patients who underwent radiofrequency ablation were at risk for perioperative death and complications. Patients who survived radiofrequency ablation and those treated with drug therapy entered a therapy-specific Markov subtree that simulated the recurrence of arrhythmic events after the initial treatment. The cycle length was 1 month. We defined an event as an arrhythmic episode that led to an unscheduled visit to either a physician's office or to an emergency department. In each treatment strategy, we assumed that half of events required treatment in the emergency department with intravenous drugs (such as adenosine or verapamil) and that half of events would be evaluated and treated in a physician's office. Under all strategies, patients were followed until death from a cause other than supraventricular tachycardia.

Patient Population

We designed our base-case analysis to reflect the observed severity of symptoms in the population from which we obtained our estimates of the effect of radiofrequency ablation on quality of life (3). This population represents

Figure 1. **Schematic representation of the decision model.**



Top. The square node at the left represents the therapy decision. If long-term drug therapy or episodic drug therapy is chosen, the patient's health state thereafter is simulated by a four-state Markov model, the follow-up subtree. In this follow-up subtree, each month, patients may experience an arrhythmic event leading to an unscheduled visit or no symptoms. The patient may die of other causes or survive and continue to be followed in the subtree. If electrophysiologic study and radiofrequency ablation (*RFA*) are chosen, the patient may have no complications, procedural complications, or procedural death. **Bottom.** If the patient survives the ablation, the patient enters the radiofrequency ablation results subtree. If radiofrequency ablation was successful, the arrhythmia may recur soon after the procedure. If the arrhythmia recurs, the patient undergoes a second ablation, with similar possible outcomes. If the radiofrequency ablation successfully cures the arrhythmia initially, the patient enters a Markov follow-up for the remainder of the lifetime. During follow-up, the patient may develop atrioventricular (*AV*) block or may continue to have events (albeit less frequently). If radiofrequency ablation failed, the patient receives the next best strategy, long-term drug therapy, and continues to receive it for the lifetime. If radiofrequency ablation induces permanent atrioventricular block, the patient is followed in a subtree (not shown) that accounts for the cost of a pacemaker. All patients are followed until death.

an unselected group of patients referred for radiofrequency ablation at the Kaiser Permanente Medical Care Program of Northern California, which cares for 2.9 million subscribers. In this population, patients receiving long-term drug therapy experienced symptoms that resulted in an average of 4.6 unscheduled visits per year. We estimated that long-term drug therapy would reduce symptoms to 40% of their frequency before treatment (60% efficacy); as a result, patients would experience approximately one event per month if they did not continue to receive therapy (4.6 events per year while receiving continuous drug therapy/0.4 = 11.5 events per year without drug therapy). Our base-case analysis evaluated alternative treatments in patients 40 years of age, and we evaluated age groups from 35 to 70 years. The quality-of-life estimates reflected a population that was composed of approximately 70% women, was physically active, and had been symptomatic for a median of 3 years.

Table 1. **Input Variables and Sources***

Input Variable	Best Estimate	Low End of Range	High End of Range	Level of Evidence†	Reference or Source
Demographic					
Starting age of population, *y*	40	30	70	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Proportion with atrioventricular nodal reentrant tachycardia	0.65	0	1	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Proportion with bypass tract	0.30	0	1	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Proportion with supraventricular tachycardia not amenable to ablation	0.05	0	0.20	III	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Events per year, *n*	11.5	0	11.5	II-2	3
Clinical					
Drug efficacy	0.60	0.40	1	III	45–69, 76
Rate of successful radiofrequency ablation for atrioventricular nodal reentrant tachycardia	0.97	0.85	0.98	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Rate of successful radiofrequency ablation for concealed bypass tract	0.93	0.75	0.98	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Rate of major complications of electrophysiologic study	0.004	0	0.012	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Rate of major complications of radiofrequency ablation	0.015	0.005	0.045	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Death caused by electrophysiologic study	0.001	0	0.003	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Immediate atrioventricular block during radiofrequency ablation for atrioventricular nodal reentrant tachycardia	0.01	0.005	0.07	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Immediate atrioventricular block during radiofrequency ablation for concealed bypass tract	0.01	0.005	0.07	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Recurring arrhythmia after radiofrequency ablation for atrioventricular nodal reentrant tachycardia	0.05	0.025	0.20	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Recurring arrhythmia after radiofrequency ablation for concealed bypass tract	0.08	0.025	0.20	I	1, 2, 4, 6–8, 12–14, 16–18, 21, 22, 26, 29–44
Costs, $‡					
Routine office visit	90	70	120	III	70, using CPT codes 93000 and 99214
Annual drug prescription	120	60	2400	III	71
Emergency department visit with follow-up office visit	640	480	800	III	70, using CPT code 99285, costs at an academic medical center (ICD 427.0, 427.89, 426.7); and published costs (72)
Electrophysiologic study (hospital and professional fees)	5260	3950	6580	III	70, using CPT codes 99245, 93621, 36620, and 93623; costs at an academic medical center (ICD 427.0, 427.89, 426.7); and published costs (23, 24, 26, 27, 72, 73)
Radiofrequency ablation, including electrophysiologic study (hospital and professional fees)	8190	6140	10 240	III	70, using CPT codes 99245, 93621, 36620, 93651, and 93623; costs at an academic medical center (ICD codes 427.0, 427.89, 426.7, 37.34); and published costs (23, 24, 26, 27, 72, 73)
Pacemaker installation	13 340	10 010	16 680	III	70, using CPT codes 33206, 93798, 99231, and 71020; costs at an academic medical center (ICD 426.0, 37.80, 37.81, 37.82, 37.83); and published costs (23, 24, 26, 27, 72, 73)
Pacemaker replacement	7640	5730	9550	III	70, using CPT codes 33212, 93732, and 99231; and costs at an academic medical center
Annual office visits because of pacemaker	220	120	280	III	70, using CPT codes 99214 and 93731
Utilities					
Patients receiving episodic drug therapy	0.828	0.495	0.945	II-2	3
Patients receiving long-term drug therapy	0.833	0.5	0.95	II-2	3
Patients cured by radiofrequency ablation	0.983	0.83	0.99	II-2	3
Patients with atrioventricular block	0.776	0.259	0.983	III	3
Disutilities (days of perfect health lost)					
Unscheduled physician visits§	0.25	0	0.5	III	Estimate
Procedural complications	1	0	7	III	Estimate
Discount rate, %	3	0	5	III	28

* The base-case estimates represent the best estimate for each value. All probabilities and mortality rates are annual unless otherwise noted. CPT = Current Procedural Terminology; ICD = International Classification of Diseases.
† Evidence rating system modified from that developed by the U.S. Preventive Services Task Force (74) to evaluate the quality of the evidence for certain model inputs. I, evidence from at least one randomized, controlled trial; II-2, evidence from at least one well-designed cohort or case–control study; III, expert judgment, clinical experience, descriptive studies, or case reports.
‡ Expressed in 1999 U.S. dollars.
§ The disutility for unscheduled events is accrued by patients receiving episodic drug therapy for only events that are in excess of the number experienced by patients receiving long-term drug therapy.

Radiofrequency Ablation

Patients assigned to the radiofrequency ablation strategy attended an initial consultation with an electrophysiologist in the clinic before the procedure. During the procedure, patients first underwent electrophysiologic study, which we estimated would establish the diagnosis of atrioventricular nodal reentrant tachycardia in 65% of patients, a concealed bypass tract in 30% of patients, and other, nonablatable arrhythmias in 5% of patients. We based these estimates on the proportions of these diagnoses reported in North American centers that had a high volume of ablation procedures and accepted pediatric and adult patients (13, 14, 16, 31, 32), excluding patients with the Wolff–Parkinson–White syndrome. The distinction between atrioventricular nodal reentrant tachycardia and supraventricular tachycardia caused by concealed bypass tract is important because rates of success, complication, and arrhythmia recurrence after radiofrequency ablation differ between the conditions (13, 14, 16, 31, 32) (**Table 1**). We assumed that patients in whom radiofrequency ablation was successful required no further antiarrhythmic medication.

We defined radiofrequency ablation as initially successful if the electrophysiologist could not induce an arrhythmia in the laboratory after the ablation session. However, some patients in whom radiofrequency ablation is initially successful subsequently experience recurrent supraventricular tachycardia, typically in the first few weeks after the procedure. Therefore, our model also incorporated 5% and 8% recurrence rates for atrioventricular nodal reentrant tachycardia and bypass tract, respectively (13, 14, 16, 31, 32) during the first month after radiofrequency ablation. At first recurrence, the patient received a second radiofrequency ablation; at second recurrence, the patient was switched to the next best therapy (episodic or long-term drug therapy). Patients were also switched to the next best therapy if the initial electrophysiologic study revealed an arrhythmia that was not ablatable or if the ablation was unsuccessful.

Long-Term Drug Therapy

Patients assigned to long-term drug therapy continued to receive a daily dose of medication but still experienced events at a reduced frequency. In our base case, we assumed that patients would be treated with generic metoprolol, which is very inexpensive (**Table 1**). Although we recognized that more expensive drugs might be used in actual practice, our choice of an inexpensive option for the base-case analysis meant that should we find radiofrequency ablation to be cost-effective, it would only be more so compared with more expensive (and potentially more toxic) drugs. After treatment of each event, we assumed that the patient had a follow-up office visit and resumed the daily drug therapy regimen without change. We also assumed that the patient would make two regular therapy-monitoring visits each year. Our estimates of quality of life accounted for decrease in quality of life caused by adverse effects of drug therapy. We assumed that the probability of an arrhythmic event for these patients was constant over time.

Episodic Drug Therapy

Patients assigned to episodic drug therapy received antiarrhythmic medication only when they experienced an event. After treatment of each event, we assumed that patients had a follow-up office visit. We assumed that patients who received episodic drug therapy made two regular monitoring visits per year to their physician.

Efficacy and Complications of Radiofrequency Ablation

Two factors complicate interpretation of the literature on radiofrequency ablation. First, the published literature may lag behind the results at the best centers; thus, reports may not reflect current complication rates or efficacy. Second, published complication rates and efficacy may not be attainable in centers with less experience. In addition to our base-case analyses, we therefore performed best- and worst-case scenario analyses in which we systematically biased the analysis for and against radiofrequency ablation.

Primarily on the basis of the most recent studies (18, 29) and additional studies from experienced centers (13, 14, 31), we estimated that the efficacy of the radiofrequency ablation procedure was 97% for patients who had atrioventricular nodal reentrant tachycardia and 93% for patients who had concealed bypass tracts. We examined lower efficacies in sensitivity analyses (36).

Our model included three categories of complications associated with the ablation procedure: complete atrioventricular node block, other major transient complications, and death. We assumed that physicians treated atrioventricular node block by implanting a permanent pacemaker, monitoring the patient with two office visits per year (76),

and replacing the pacemaker every 8 years on average. On the basis of studies from experienced centers, we estimated that the probability of developing complete atrioventricular node block as a result of ablation is 1.0% for patients who have atrioventricular nodal reentrant tachycardia and those who have a concealed bypass tract (13, 14, 16, 18, 29, 31, 32). We estimated that the probability of other major complications that would require additional hospitalization, including cardiac tamponade, embolic events, cardiac perforations, and stroke, was 1.5% (18, 22) and that the probability of death caused by radiofrequency ablation was 0.1% (**Table 1**). As noted above, some experienced centers may now have lower complication rates than published studies suggest. We examine lower rates in our best-case scenario.

Efficacy of Drug Therapy

Studies of the efficacy of drug therapy for supraventricular tachycardia are difficult to interpret because they use different drugs, have varying follow-up periods, use different definitions of success, often do not document the severity of supraventricular tachycardia before initiation of drug therapy, and often have uncontrolled nonrandomized designs (26, 45–69, 77–79). On the basis of our literature review, we estimated that drug therapy reduces the risk for an arrhythmic episode by 60% compared with no therapy. Because the efficacy of therapy may vary by drug and by individual patients, we performed sensitivity analyses on drug efficacy to assure the robustness of results across a wide range of efficacies. We assumed that the effect of the medication on a patient's probability of experiencing an event remained constant throughout the patient's lifetime.

Quality of Life

Therapies for non–life-threatening supraventricular tachycardia by definition affect quality of life rather than length of life. Therefore, the effectiveness of therapy depends on the degree to which symptoms are ameliorated. Larson and colleagues (3) performed telephone interviews with 161 patients who had undergone radiofrequency ablation for atrioventricular nodal reentrant tachycardia (3) and assessed the patients' symptoms, pharmacologic therapy, and utilities. We assumed that the symptoms from supraventricular tachycardia due to atrioventricular nodal reentrant tachycardia or concealed bypass tract are not distinguishable; thus, Larson and colleagues' findings are applicable to our population.

Of the 161 patients, 135 (84%) had been receiving drug therapy before the ablation and had experienced an average of 4.6 symptoms of medium or high severity. After the ablation procedure, all patients reported a decrease in moderate or severe symptoms (mean number of symptoms, 1.1; $P < 0.001$). Patients reported an average of 4.6 unscheduled visits per year before radiofrequency ablation and an average of 0.4 unscheduled visits after radiofrequency ablation, including procedures that were not successful.

The investigators assessed utilities by asking patients to rate their quality of life before and after radiofrequency ablation by using the time-tradeoff technique (80). Utilities assess how patients value health states and typically range from 0, representing death, to 1, representing ideal health. Utilities differ from measures of functional status in that they assess how much a health state bothers patients rather than describing the health state in terms of what patients can do. The median utility for health status was 0.833 before radiofrequency ablation and 0.983 after radiofrequency ablation (3), a substantial improvement.

We used the measured utilities after radiofrequency ablation as the utilities for patients who had successful radiofrequency ablation; we used utilities before radiofrequency ablation as the utility for patients receiving long-term drug therapy. For patients receiving episodic drug therapy, we decreased their utility by 0.25 quality-adjusted life-days (**Table 1**) for each event in excess of those experienced by patients receiving long-term drug therapy. We assumed that the utility of atrioventricular node block was 90% of the median utility after radiofrequency ablation, and we evaluated much lower utilities in sensitivity analyses.

Costs

We included in our analysis direct costs of care related to supraventricular tachycardia and lifetime medical expenditures unrelated to arrhythmia therapy (81). We estimated hospital utilization and costs related to supraventricular tachycardia from a cohort of 60 patients seen at a major academic hospital between 1997 and 1998 (Unpublished data; cost calculated by using Sunrise Suite, Eclipsys Corp., Delray Beach, Florida), as well as published data on costs (23, 24, 26, 27, 72, 73) (**Table 1**). These estimates included the cost of electrophysiologic study, radiofrequency

Table 2. **Health and Economic Outcomes***

Strategy	Lifetime Cost	Incremental Cost†	Quality-Adjusted Life Expectancy	Incremental Quality-Adjusted Life Expectancy†	Life Expectancy	Incremental Life Expectancy†
	$		y	y, d	y	y, d
Radiofrequency ablation	61 880	−81 640	21.66	3, 75	22.26	−0, −8.8
Long-term drug therapy	89 820	−53 700	18.56	0, 38	22.28	0, 0
Episodic drug therapy	143 530	–	18.46	–	22.28	–

* Costs are expressed in 1999 U.S. dollars. All costs and benefits are discounted at 3% annually.
† Incremental costs and life expectancies are calculated in comparison with episodic drug therapy.

ablation, concomitant 1-day hospitalization, and implantation of a pacemaker in the event that radiofrequency ablation produced atrioventricular node block. We calculated mean costs of an emergency department visit to the same institution for patients who had a diagnosis of supraventricular tachycardia (**Table 1**). We also compared these costs to relevant Medicare reimbursement.

We estimated professional fees by using the 1998 National Physician Fee Schedule Relative Value File (82). We included costs associated with office visits, electrocardiographic monitoring, electrophysiologic studies, radiofrequency ablation, pacemaker implantation and replacement, and emergency department visits. We estimated wholesale drug costs by using the Red Book (71), and we assumed that patients would be prescribed metoprolol. As noted, we also evaluated higher drug costs because in practice, some patients would probably receive more expensive drug therapy. We adjusted all costs to 1999 U.S. dollars by using a gross domestic product deflator (83, 84) and evaluated both lower and higher costs in sensitivity analyses.

Role of the Funding Sources

The study was funded by the Agency for Healthcare Research and Quality and the Health Services Research and Development Service of the Department of Veterans Affairs. The authors had complete independence in the design, conduct, and reporting of the study.

RESULTS

Model Validation

We evaluated outcomes in the model to ensure that they reflected the frequency of events described in the cohort on which we based our quality-of-life estimates. The model accurately reflected the frequency of 4.6 events per year for patients receiving long-term drug therapy.

Base-Case Results

In a population of patients with monthly episodes of supraventricular tachycardia, radiofrequency ablation was the most effective and least expensive therapy (**Table 2**). Radiofrequency ablation improved quality-adjusted life expectancy by 3.10 quality-adjusted life-years (QALYs) and reduced lifetime medical expenditures by $27 900 compared with long-term drug therapy. Long-term drug therapy was more effective and had lower costs than episodic drug therapy (**Table 2**). If we excluded the effect of radiofrequency ablation on quality of life, drug therapy produced slightly longer life expectancy because of the small risk for death associated with radiofrequency ablation (0.1%).

In patients who had monthly episodes of supraventricular tachycardia, the initial cost of radiofrequency ablation ($8740) was ultimately recouped by saving the cost of treating supraventricular tachycardia episodes and administering drugs (**Table 3**). For patients receiving long-term drug therapy, the lifetime cost of unscheduled visits to the emergency department or a physician was $37 610. For patients initially treated with radiofrequency ablation, the lifetime cost of unscheduled visits was only $4950 (the costs incurred by patients who were not cured by the ablation procedure).

Sensitivity Analyses

Although radiofrequency ablation reduced lifetime medical costs compared with drug therapy in our base-case analysis, this analysis assumed that patients were severely symptomatic. Whether radiofrequency ablation reduced net expenditures depended on the frequency of unscheduled visits and the cost of drug therapy (**Figure 2**). Radiofrequency ablation provides lifetime cost savings for patients who have more than one event per year and a

Table 3. **Lifetime Costs Incurred by Patients with Supraventricular Tachycardia***

Strategy	Radiofrequency Ablation Procedure	Atrioventricular Block	Monthly Drug Cost	Unscheduled Physician Visits	Scheduled Office Visits	Expenditures for Other Medical Conditions	Total
	←			$			→
Radiofrequency ablation	8740	550	160	4950	120	47 370†	61 880
Long-term drug therapy	0	0	2710	37 610	2080	47 420	89 820
Episodic drug therapy	0	0	0	94 030	2080	47 420	143 530

* Costs are expressed in 1999 U.S. dollars and are discounted at 3% annually.
† Because there is a small chance of death during radiofrequency ablation, patients who receive radiofrequency ablation have lower medical expenditures for other unrelated medical conditions.

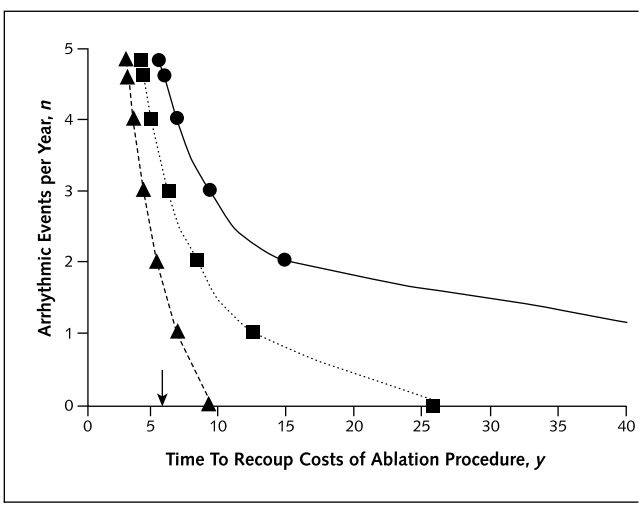
monthly drug cost of $10 or more (**Figure 2**). As drug therapy became more expensive (as would be the case for drugs other than metoprolol), the time to recoup costs was substantially shortened. The time to recoup the costs after radiofrequency ablation was inversely proportional to the frequency of events and monthly drug costs. For patients who had less than one event per year and whose drug therapy cost less than $10 per month, savings from subsequent therapy for supraventricular tachycardia did not recoup the cost of radiofrequency ablation.

Because we modeled highly symptomatic patients, our base-case estimates of the benefit from radiofrequency ablation cannot be generalized to patients whose symptoms are less severe or less frequent. To examine the cost-effectiveness of radiofrequency ablation in less symptomatic patients, we evaluated the costs and benefits of treatment if the improvement in quality of life after radiofrequency ablation was substantially less than in our base case. **Table 4** shows the net gain in QALYs and changes in costs if radiofrequency ablation provided an increase in quality of life of only 0.01 (approximately one fifteenth of the base-case increase). Radiofrequency ablation remained cost saving, even with this small increment in quality of life, if the annual costs of the long-term drug strategy (including physician and emergency department visits) were about $500 or more (base-case estimate, approximately $1900 annually). The important implication of the data in **Table 4** is that radiofrequency ablation can be cost-effective or cost saving, even if the treatment provides only small gains in utility—of about 1% at most—and even if the costs of medical therapy are substantially lower than the base-case estimates.

In our base-case analysis, we estimated that the probability of complete atrioventricular node block after radiofrequency ablation was 1.0% for patients with atrioventricular nodal reentrant tachycardia and those with a concealed bypass tract. Higher rates of postprocedure atrioventricular node block have been reported (16, 32). One-way sensitivity analysis of the rate of atrioventricular node block showed that even if the rate were doubled, radiofrequency ablation would still result in an increase of 3.08 QALYs and a decrease of $27 500 in expenditures compared with long-term drug therapy. If the quality of life with a pacemaker is only 40% of that without one, our results are unchanged.

Because low-volume or less experienced centers may not achieve radiofrequency ablation outcomes comparable to the results reported by leading centers, we also evaluated

Figure 2. **Years required to recoup costs of radiofrequency ablation, given different monthly costs of drug therapy.**



The analysis includes all costs of medical therapy, including drug costs, physician visits, and treatment in emergency departments. Triangles represent a monthly drug cost of $10 (base case), squares represent a monthly drug cost of $50, and circles represent a monthly drug cost of $100. The vertical axis represents the number of arrhythmic events per year the patient experiences while receiving long-term drug therapy. The horizontal axis shows the number of years after radiofrequency ablation until the cumulative cost of that strategy would be less than the cost of the long-term drug strategy. Costs are recouped more quickly for patients who have more frequent arrhythmic events and for patients whose drug therapy is more expensive. The time to recoup costs for the base-case analysis is shown by the arrow.

Table 4. **Incremental Costs, Incremental Benefits, and Cost-Effectiveness of Radiofrequency Ablation Compared with Long-Term Drug Therapy***

Annual Cost of Long-Term Drug Therapy	Increase in Quality of Life with RFA											
	0.01			0.05			0.1			0.15		
	Cost	Benefit	MCE	Cost	Benefit	MCE	Cost	Benefit	MCE	Cost	Benefit	MCE
	$	*QALY*	*$/QALY*	*$*	*QALY*	*$/QALY*	*$*	*QALY*	*$/QALY*	*$*	*QALY*	*$/QALY*
$250	4000	0.170	23 500	4000	0.999	4000	4000	2.035	2000	4000	3.072	1300
$500	(1300)	0.170	RFA dominates	(1300)	0.999	RFA dominates	(1300)	2.035	RFA dominates	(1300)	3.072	RFA dominates
$750	(6500)	0.170	RFA dominates	(6500)	0.999	RFA dominates	(6500)	2.035	RFA dominates	(6500)	3.072	RFA dominates
$1000	(11 700)	0.170	RFA dominates	(11 700)	0.999	RFA dominates	(11 700)	2.035	RFA dominates	(11 700)	3.072	RFA dominates

* Costs are expressed in 1999 U.S. dollars. Costs and benefits have been discounted at 3%. Values in parentheses represent cost savings with radiofrequency ablation compared with long-term drug therapy. MCE = marginal cost-effectiveness; QALY = quality-adjusted life-year; RFA = radiofrequency ablation.

scenarios in which the rate of radiofrequency ablation procedural complications, procedural death, and arrhythmia recurrence were twice and three times the base-case estimate. For a twofold increase in complications, we assumed that the probability of successful radiofrequency ablation was 0.90 for patients with atrioventricular nodal reentrant tachycardia (base-case estimate, 0.97) and 0.80 for those with a concealed bypass tract (base-case estimate, 0.93). For a threefold increase in complication rates, we reduced these efficacies to 0.85 and 0.75, respectively. Despite substantial increases in the rate of unsuccessful procedures and complications in these scenarios, radiofrequency ablation still dominated drug therapy in severely symptomatic patients (**Table 5**).

We also evaluated a best-case scenario in which we reduced the rate of complications to one third the base-case rate. With these assumptions, radiofrequency ablation continued to dominate drug therapy; compared with base-case values, it resulted in more health benefit (21.71 vs. 21.66 QALYs) and lower expenditure ($61 200 vs. $61 880).

Table 5. **Health and Economic Outcomes When Efficacy of Radiofrequency Ablation Is Reduced and Complication Rate Is Increased***

Strategy	Cost, *$*	Quality-Adjusted Life Expectancy, *y*
Radiofrequency ablation		
Best case†	61 220	21.71
Base case	61 880	21.66
Twofold increase	64 680	21.48
Threefold increase	67 400	21.28
Long-term drug therapy	89 820	18.56
Episodic drug therapy	143 530	18.46

* Costs are expressed in 1999 U.S. dollars. All costs and benefits are discounted at 3% annually.
† In the best-case scenario, the rate of complications was reduced to one third the base-case rate.

We also assessed whether changes in our estimate of the efficacy of drug therapy affected our results. In the base-case analysis, we assumed that drug therapy reduced the frequency of arrhythmic episodes by 60%. Even if drug therapy reduced arrhythmic episodes by 90%, radiofrequency ablation still provides savings of $1400.

Sensitivity analyses on other variables did not change our results significantly. If radiofrequency ablation is performed in patients 70 years of age rather than the base-case age of 40 years, it still reduces expenditures ($43 400 vs. $52 100) and provides more health benefit (10.39 vs. 8.90 QALYs) than does long-term drug therapy. Increasing the discount rate to 5% did not substantially alter our results, and radiofrequency ablation still dominated drug therapy.

We performed a probabilistic sensitivity analysis in which we simultaneously varied all of the values for the variables listed in **Table 1**. In this analysis, radiofrequency ablation dominated long-term drug therapy in 93.7% of the simulations, and it was more effective yet more costly in an additional 2.2% of simulations (median cost-effectiveness ratio, $1600 per QALY). Long-term drug therapy was, in turn, a dominant strategy in comparison with episodic drug therapy in 99.8% of the simulations.

DISCUSSION

We evaluated the cost-effectiveness of radiofrequency ablation relative to that of long-term or episodic drug therapy in patients who have frequent symptoms of supraventricular tachycardia requiring medical intervention. Our analyses indicate that in severely symptomatic patients (those who have approximately one episode of supraventricular tachycardia per month without treatment), radiofrequency ablation improves quality-adjusted survival and

reduces lifetime medical expenditures. The higher initial cost of radiofrequency ablation was ultimately recouped by eliminating the need for long-term drug therapy and frequent unscheduled visits to an emergency department or a physician's office. Given that many centers have high success rates (97% for atrioventricular nodal reentrant tachycardia) and low complication rates (atrioventricular node block < 1.5%), radiofrequency ablation is an example of a new technology that is more effective therapeutically and that reduces rather than increases costs.

Our model used a lifetime projection of the costs of care for patients who have supraventricular tachycardia. Radiofrequency ablation was cost saving in the long term for severely symptomatic patients, but the time required to recoup the initial cost of radiofrequency ablation may be 10 years or more (**Figure 2**). The cost savings ultimately result from reduction in the cost of treating acute supraventricular tachycardia episodes and monitoring long-term drug regimens prescribed to prevent recurrent arrhythmias. Because the annual cost of medical management is higher in patients who have more frequent episodes, the time to recoup the cost of radiofrequency ablation is shorter in more severely symptomatic patients (**Figure 2**). In addition, our base-case assumption about the cost of drug therapy was optimistic; in many cases, patients would be treated with more expensive medications, and radiofrequency ablation would therefore provide even greater relative cost savings. In patients with very infrequent symptoms, the lifetime cost of radiofrequency ablation will be higher than that of medical management.

Our cost-effectiveness analysis is the first to use utilities assessed from patients to estimate the benefit from radiofrequency ablation. The patients who provided the data were receiving long-term drug therapy before radiofrequency ablation and were severely symptomatic, with a mean of 4.6 unscheduled physician visits per year because of arrhythmic episodes. Because these patients rated their quality of life as much higher after radiofrequency ablation and because of their long life expectancy after the procedure, the improvement in QALYs (3.10) was substantial. In contrast, many interventions that are commonly considered effective, such as screening for breast or colon cancer, increase quality-adjusted survival by only a few months (85, 86).

Although the benefit of radiofrequency ablation in highly symptomatic patients is clear, the question of how to manage patients whose symptoms are minimal or modest remains. Our base-case results cannot be extrapolated to such patients because the improvement in quality of life from radiofrequency ablation will be less for patients who have fewer symptoms before the procedure. Relatively small improvements in quality of life after radiofrequency ablation are important because the improvements persist for the patient's remaining lifetime. For patients who are minimally symptomatic, the possibility of complications, even if remote, may be a more important consideration. However, our sensitivity analyses indicated that radiofrequency ablation need only provide a small increment in quality of life to be preferred.

Given the importance of patients' rating of quality of life for the evaluation of radiofrequency ablation, the limitations of the data that we used on quality of life must be considered. Patients assessed their quality of life by using the time-tradeoff method, a widely used and reliable technique (80). However, the assessments were made by means of a telephone survey, and one of the assessments (quality of life before radiofrequency ablation) was retrospective. Few reports of assessments performed by telephone have been published; one recent study suggested that utilities assessed in this manner provide results similar to those collected in face-to-face interviews (87). Whether retrospectively assessed quality-of-life assessments agree with prospectively assessed preintervention and postintervention measures does not seem to have been evaluated. These limitations raise the question of whether the quality-of-life assessments that we used overestimated the benefit of radiofrequency ablation. As demonstrated by our sensitivity analyses, however, even if the benefit from radiofrequency ablation is reduced by a factor of 10, the procedure still improves quality-adjusted survival compared with long-term drug therapy.

In summary, radiofrequency ablation substantially improves quality of life and reduces expenditures when used to treat severely symptomatic patients. This finding is highly robust, even when we varied our assumptions about the efficacy and complication rate of radiofrequency ablation. In addition, patients for whom the cost of medical therapy is more than approximately $450 per year are reasonable candidates for radiofrequency ablation. Although the magnitude of benefit after radiofrequency ablation in minimally symptomatic patients has not been studied adequately, only a small incremental benefit is required for radiofrequency ablation to be cost-effective.

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References

1. **Orejarena LA, Vidaillet H Jr, DeStefano F, Nordstrom DL, Vierkant RA, Smith PN, et al.** Paroxysmal supraventricular tachycardia in the general population. J Am Coll Cardiol. 1998;31:150-7. [PMID: 0009426034]

2. **Ganz LI, Friedman PL.** Supraventricular tachycardia. N Engl J Med. 1995; 332:162-73. [PMID: 0007800009]

3. **Larson MS, McDonald K, Young C, Sung R, Hlatky MA.** Quality of life before and after radiofrequency catheter ablation in patients with drug refractory atrioventricular nodal reentrant tachycardia. Am J Cardiol. 1999;84:471-3. [PMID: 0010468092]

4. Catheter ablation for cardiac arrhythmias: clinical applications, personnel and facilities. American College of Cardiology Cardiovascular Technology Assessment Committee. J Am Coll Cardiol. 1994;24:828-33. [PMID: 0008077560]

5. **Kay GN, Plumb VJ.** The present role of radiofrequency catheter ablation in the management of cardiac arrhythmias. Am J Med. 1996;100:344-56. [PMID: 0008629682]

6. **Manolis AS, Wang PJ, Estes NA 3rd.** Radiofrequency catheter ablation for cardiac tachyarrhythmias. Ann Intern Med. 1994;121:452-61. [PMID: 0008053620]

7. **Stevenson WG, Ellison KE, Lefroy DC, Friedman PL.** Ablation therapy for cardiac arrhythmias. Am J Cardiol. 1997;80:56G-66G. [PMID: 0009354412]

8. **Scheinman MM.** Radiofrequency catheter ablation for patients with supraventricular tachycardia. Pacing Clin Electrophysiol. 1993;16:671-9. [PMID: 0007681973]

9. **Morady F.** Radio-frequency ablation as treatment for cardiac arrhythmias. N Engl J Med. 1999;340:534-44. [PMID: 0010021475]

10. **Graves EJ, Kozak LJ, eds.** Detailed Diagnoses and Procedures, National Hospital Discharge Survey, 1996. vol. 138. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics; 1998.

11. **Graves EJ, ed.** Detailed Diagnoses and Procedures, National Hospital Discharge Survey, 1990. vol. 113. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics; 1990.

12. **Basta MN, Krahn AD, Klein GJ, Rosenbaum M, Le Feuvre C, Yee R.** Safety of slow pathway ablation in patients with atrioventricular node reentrant tachycardia and a long fast pathway effective refractory period. Am J Cardiol. 1997;80:155-9. [PMID: 0009230151]

13. **Kay GN, Epstein AE, Dailey SM, Plumb VJ.** Role of radiofrequency ablation in the management of supraventricular arrhythmias: experience in 760 consecutive patients. J Cardiovasc Electrophysiol. 1993;4:371-89. [PMID: 0008269306]

14. **Kugler JD, Danford DA, Houston K, Felix G.** Radiofrequency catheter ablation for paroxysmal supraventricular tachycardia in children and adolescents without structural heart disease. Pediatric EP Society, Radiofrequency Catheter Ablation Registry. Am J Cardiol. 1997;80:1438-43. [PMID: 0009399718]

15. **Mehta D, Gomes JA.** Long term results of fast pathway ablation in atrioventricular nodal reentry tachycardia using a modified technique. Br Heart J. 1995; 74:671-5. [PMID: 0008541176]

16. **Scheinman MM.** NASPE Survey on Catheter Ablation. Pacing Clin Electrophysiol. 1995;18:1474-8. [PMID: 0007479168]

17. **Talwar KK, Singh B, Goel P, Bahl VK, Kaul U, Wasir HS.** In-hospital results of radiofrequency ablation of supraventricular tachycardia. Indian Heart J. 1996;48:685-90. [PMID: 0009062019]

18. **Calkins H, Yong P, Miller JM, Olshansky B, Carlson M, Saul JP, et al.** Catheter ablation of accessory pathways, atrioventricular nodal reentrant tachycardia, and the atrioventricular junction: final results of a prospective, multicenter

clinical trial. The Atakr Multicenter Investigators Group. Circulation. 1999;99: 262-70. [PMID: 0009892593]

19. **Bubien RS, Knotts-Dolson SM, Plumb VJ, Kay GN.** Effect of radiofrequency catheter ablation on health-related quality of life and activities of daily living in patients with recurrent arrhythmias. Circulation. 1996;94:1585-91. [PMID: 0008840848]

20. **Lau CP, Tai YT, Lee PW.** The effects of radiofrequency ablation versus medical therapy on the quality-of-life and exercise capacity in patients with accessory pathway-mediated supraventricular tachycardia: a treatment comparison study. Pacing Clin Electrophysiol. 1995;18:424-32. [PMID: 0007770362]

21. **Thakur RK, Klein GJ, Yee R, Guiraudon GM.** Complications of radiofrequency catheter ablation: a review. Can J Cardiol. 1994;10:835-9. [PMID: 0007954019]

22. **Chen SA, Chiang CE, Tai CT, Cheng CC, Chiou CW, Lee SH, et al.** Complications of diagnostic electrophysiologic studies and radiofrequency catheter ablation in patients with tachyarrhythmias: an eight-year survey of 3,966 consecutive procedures in a tertiary referral center. Am J Cardiol. 1996;77:41-6. [PMID: 0008540455]

23. **de Buitleir M, Bove EL, Schmaltz S, Kadish AH, Morady F.** Cost of catheter versus surgical ablation in the Wolff-Parkinson-White syndrome. Am J Cardiol. 1990;66:189-92. [PMID: 0002371949]

24. **Man KC, Kalbfleisch SJ, Hummel JD, Williamson BD, Vorperian VR, Strickberger SA, et al.** Safety and cost of outpatient radiofrequency ablation of the slow pathway in patients with atrioventricular nodal reentrant tachycardia. Am J Cardiol. 1993;72:1323-4. [PMID: 0008256715]

25. **Kertes PJ, Kalman JM, Tonkin AM.** Cost effectiveness of radiofrequency catheter ablation in the treatment of symptomatic supraventricular tachyarrhythmias. Aust N Z J Med. 1993;23:433-6. [PMID: 0008240167]

26. **Kalbfleisch SJ, Calkins H, Langberg JJ, el-Atassi R, Leon A, Borganelli M, et al.** Comparison of the cost of radiofrequency catheter modification of the atrioventricular node and medical therapy for drug-refractory atrioventricular node reentrant tachycardia. J Am Coll Cardiol. 1992;19:1583-7. [PMID: 0001593054]

27. **Hogenhuis W, Stevens SK, Wang P, Wong JB, Manolis AS, Estes NA 3rd, et al.** Cost-effectiveness of radiofrequency ablation compared with other strategies in Wolff-Parkinson-White syndrome. Circulation. 1993;88:II437-46. [PMID: 0008222191]

28. **Gold MR, Siegel JE, Russell LB, Weinstein MC, eds.** Cost-Effectiveness in Health and Medicine. New York: Oxford Univ Pr; 1996.

29. **Scheinman MM, Huang S.** The 1998 NASPE prospective catheter ablation registry. Pacing Clin Electrophysiol. 2000;23:1020-8. [PMID: 0010879389]

30. **Baker JH 2nd, Plumb VJ, Epstein AE, Kay GN.** Predictors of recurrent atrioventricular nodal reentry after selective slow pathway ablation. Am J Cardiol. 1994;73:765-9. [PMID: 0008160613]

31. **Calkins H, Prystowsky E, Berger RD, Saul JP, Klein LS, Liem LB, et al.** Recurrence of conduction following radiofrequency catheter ablation procedures: relationship to ablation target and electrode temperature. The Atakr Multicenter Investigators Group. J Cardiovasc Electrophysiol. 1996;7:704-12. [PMID: 0008856461]

32. **Hindricks G.** The Multicentre European Radiofrequency Survey (MERFS): complications of radiofrequency catheter ablation of arrhythmias. The Multicentre European Radiofrequency Survey (MERFS) investigators of the Working Group on Arrhythmias of the European Society of Cardiology. Eur Heart J. 1993;14:1644-53. [PMID: 0008131762]

33. **Hindricks G.** Incidence of complete atrioventricular block following attempted radiofrequency catheter modification of the atrioventricular node in 880 patients. Results of the Multicenter European Radiofrequency Survey (MERFS) The Working Group on Arrhythmias of the European Society of Cardiology. Eur Heart J. 1996;17:82-8. [PMID: 0008682135]

34. **Iesaka Y, Takahashi A, Goya M, Yamane T, Kojima S, Fujiwara H, et al.** Selective radiofrequency catheter ablation of the slow pathway for common and uncommon atrioventricular nodal reentrant tachycardia. Jpn Heart J. 1996;37: 759-70. [PMID: 0008973388]

35. **Jackman WM, Beckman KJ, McClelland JH, Wang X, Friday KJ, Roman CA, et al.** Treatment of supraventricular tachycardia due to atrioventricular nodal reentry, by radiofrequency catheter ablation of slow-pathway conduction. N Engl J Med. 1992;327:313-8. [PMID: 0001620170]

36. **Leather RA, Leitch JW, Klein GJ, Guiraudon GM, Yee R, Kim YH.** Radiofrequency catheter ablation of accessory pathways: a learning experience. Am J Cardiol. 1991;68:1651-5. [PMID: 0001746468]

37. **Lesh MD, Van Hare GF, Schamp DJ, Chien W, Lee MA, Griffin JC, et al.** Curative percutaneous catheter ablation using radiofrequency energy for accessory pathways in all locations: results in 100 consecutive patients. J Am Coll Cardiol. 1992;19:1303-9. [PMID: 0001564231]

38. **Lin JL, Stephen Huang SK, Lai LP, Ko WC, Tseng YZ, Lien WP.** Clinical and electrophysiologic characteristics and long-term efficacy of slow-pathway catheter ablation in patients with spontaneous supraventricular tachycardia and dual atrioventricular node pathways without inducible tachycardia. J Am Coll Cardiol. 1998;31:855-60. [PMID: 0009525559]

39. **Prystowsky EN.** Atrioventricular node reentry: physiology and radiofrequency ablation. Pacing Clin Electrophysiol. 1997;20:552-71. [PMID: 0009058855]

40. **Scheinman MM.** Catheter ablation for cardiac arrhythmias, personnel, and facilities. North American Society of Pacing and Electrophysiology Ad Hoc Committee on Catheter Ablation. Pacing Clin Electrophysiol. 1992;15:715-21. [PMID: 0001382271]

41. **Sakurada H, Okazaki H, Motomiya T, Hiraoka M.** Catheter ablation for the common type of atrioventricular nodal reentrant tachycardia. Jpn Heart J. 1996;37:751-8. [PMID: 0008973387]

42. **Strickberger SA, Okishige K, Meyerovitz M, Shea J, Friedman PL.** Evaluation of possible long-term adverse consequences of radiofrequency ablation of accessory pathways. Am J Cardiol. 1993;71:473-5. [PMID: 0008430649]

43. **Sung RJ, Lauer MR, Chun H.** Atrioventricular node reentry: current concepts and new perspectives. Pacing Clin Electrophysiol. 1994;17:1413-30. [PMID: 0007971402]

44. **Trohman RG, Pinski SL, Sterba R, Schutzman JJ, Kleman JM, Kidwell GA.** Evolving concepts in radiofrequency catheter ablation of atrioventricular nodal reentry tachycardia. Am Heart J. 1994;128:586-95. [PMID: 0008074023]

45. **Anderson JL, Jolivette DM, Fredell PA.** Summary of efficacy and safety of flecainide for supraventricular arrhythmias. Am J Cardiol. 1988;62:62D-66D. [PMID: 0003136638]

46. **Anderson JL.** Long-term safety and efficacy of flecainide in the treatment of supraventricular tachyarrhythmias: the United States experience. The Flecainide Supraventricular Tachyarrhythmia Investigators. Am J Cardiol. 1992;70:11A-17A. [PMID: 0001509993]

47. **Zee-Cheng CS, Kim SS, Ruffy R.** Flecainide acetate for treatment of bypass tract mediated reentrant tachycardia. Am J Cardiol. 1988;62:23D-28D. [PMID: 0003136631]

48. **Clair WK, Wilkinson WE, McCarthy EA, Pritchett EL.** Treatment of paroxysmal supraventricular tachycardia with oral diltiazem. Clin Pharmacol Ther. 1992;51:562-5. [PMID: 0001587069]

49. **Dimich II, Steinfeld L, Richman R, Lasser R.** Treatment of recurrent paroxysmal ventricular tachycardia. Am Heart J. 1970;79:811-5. [PMID: 0005419354]

50. **Dorian P, Naccarelli GV, Coumel P, Hohnloser SH, Maser MJ.** A randomized comparison of flecainide versus verapamil in paroxysmal supraventricular

tachycardia. The Flecainide Multicenter Investigators Group. Am J Cardiol. 1996;77:89A-95A. [PMID: 0008607397]

51. A randomized, placebo-controlled trial of propafenone in the prophylaxis of paroxysmal supraventricular tachycardia and paroxysmal atrial fibrillation. UK Propafenone PSVT Study Group. Circulation. 1995;92:2550-7. [PMID: 0007586356]

52. **Hamer AW, Strathmore N, Vohra JK, Hunt VD.** Oral flecainide, sotalol, and verapamil for the termination of paroxysmal supraventricular tachycardia. Pacing Clin Electrophysiol. 1993;16:1394-400. [PMID: 0007689205]

53. **Harris A.** Long term treatment of paroxysmal cardiac arrhythmias with propranolol. Am J Cardiol. 1966;18:431-7. [PMID: 0004162493]

54. **Henthorn RW, Waldo AL, Anderson JL, Gilbert EM, Alpert BL, Bhandari AK, et al.** Flecainide acetate prevents recurrence of symptomatic paroxysmal supraventricular tachycardia. The Flecainide Supraventricular Tachycardia Study Group. Circulation. 1991;83:119-25. [PMID: 0001898640]

55. **Huycke EC, Sung RJ, Dias VC, Milstein S, Hariman RJ, Platia EV.** Intravenous diltiazem for termination of reentrant supraventricular tachycardia: a placebo-controlled, randomized, double-blind, multicenter study. J Am Coll Cardiol. 1989;13:538-44. [PMID: 0002918157]

56. **Klein GJ, Yee R, Leitch JW.** Pharmacological management of supraventricular tachycardia. Pacing Clin Electrophysiol. 1990;13:1516-24. [PMID: 0001702531]

57. **Krikler DM.** Uses of calcium channel blocking agents and beta blocking agents in the control of supraventricular arrhythmias. Prog Clin Biol Res. 1988; 275:301-17. [PMID: 0002902640]

58. **Kubik MM, Gill B, Dawes PM.** Propranolol in cardiac arrhythmias: a comparative study of the conventional and long-acting formulations. Curr Med Res Opin. 1986;10:215-20. [PMID: 0003780285]

59. **Lee KL, Tai YT.** Long-term low-dose amiodarone therapy in the management of ventricular and supraventricular tachyarrhythmias: efficacy and safety. Clin Cardiol. 1997;20:372-7. [PMID: 0009098598]

60. **Margolis B, DeSilva RA, Lown B.** Episodic drug treatment in the management of paroxysmal arrhythmias. Am J Cardiol. 1980;45:621-6. [PMID: 0007355758]

61. **Mauritson DR, Winniford MD, Walker WS, Rude RE, Cary JR, Hillis LD.** Oral verapamil for paroxysmal supraventricular tachycardia: a long-term, double-blind randomized trial. Ann Intern Med. 1982;96:409-12. [PMID: 0007065555]

62. **Neuss H, Schlepper M.** Long-term efficacy and safety of flecainide for supraventricular tachycardia. Am J Cardiol. 1988;62:56D-61D. [PMID: 0003136637]

63. **Pritchett EL, Hammill SC, Reiter MJ, Lee KL, McCarthy EA, Zimmerman JM, et al.** Life-table methods for evaluating antiarrhythmic drug efficacy in patients with paroxysmal atrial tachycardia. Am J Cardiol. 1983;52:1007-12. [PMID: 0006356859]

64. **Pritchett EL, McCarthy EA, Wilkinson WE.** Propafenone treatment of symptomatic paroxysmal supraventricular arrhythmias. A randomized, placebo-controlled, crossover trial in patients tolerating oral therapy. Ann Intern Med. 1991;114:539-44. [PMID: 0002001087]

65. **Prystowsky EN.** Inpatient versus outpatient initiation of antiarrhythmic drug therapy for patients with supraventricular tachycardia. Clin Cardiol. 1994;17:II7-10. [PMID: 0007882612]

66. **Scheinman M.** Supraventricular tachyarrhythmias: drug therapy versus catheter ablation. Clin Cardiol. 1994;17:II11-5. [PMID: 0007882608]

67. **Szekely P, Jackson F, Wynne NA, Vohra JK, Batson GA, Dow WI.** Clinical observations on the use of propranolol in disorders of cardiac rhythm. Am J Cardiol. 1966;18:426-30. [PMID: 0004162492]

68. **Winniford MD, Fulton KL, Hillis LD.** Long-term therapy of paroxysmal supraventricular tachycardia: a randomized, double-blind comparison of digoxin, propranolol and verapamil. Am J Cardiol. 1984;54:1138-9. [PMID: 0006388299]

69. **Yeh SJ, Kou HC, Lin FC, Hung JS, Wu D.** Effects of oral diltiazem in paroxysmal supraventricular tachycardia. Am J Cardiol. 1983;52:271-8. [PMID: 0006869272]

70. Current Procedural Terminology. Chicago: American Medical Assoc; 1998.

71. Red Book. Montvale, NJ: Medical Economics; 1998.

72. **Bathina MN, Mickelsen S, Brooks C, Jaramillo J, Hepton T, Kusumoto FM.** Radiofrequency catheter ablation versus medical therapy for initial treatment of supraventricular tachycardia and its impact on quality of life and healthcare costs. Am J Cardiol. 1998;82:589-93. [PMID: 0009732885]

73. **Kalbfleisch SJ, el-Atassi R, Calkins H, Langberg JJ, Morady F.** Safety, feasibility and cost of outpatient radiofrequency catheter ablation of accessory atrioventricular connections. J Am Coll Cardiol. 1993;21:567-70. [PMID: 0008436736]

74. U.S. Preventive Services Task Force. Guide to Clinical Preventive Services: Report of the U.S. Preventive Services Task Force. 2nd ed. Baltimore: Williams & Wilkins; 1996:861-2.

75. **Sonnenberg FA, Beck JR.** Markov models in medical decision making: a practical guide. Med Decis Making. 1993;13:322-38. [PMID: 0008246705]

76. **Bernstein AD, Irwin ME, Parsonnet VV, Wilkoff BL, Black WR, Buckingham TA, et al.** Report of the NASPE Policy Conference on antibradycardia pacemaker follow-up: effectiveness, needs, and resources. North American Society of Pacing and Electrophysiology. Pacing Clin Electrophysiol. 1994;17:1714-29. [PMID: 0007838779]

77. **Basta M, Klein GJ, Yee R, Krahn A, Lee J.** Current role of pharmacologic therapy for patients with paroxysmal supraventricular tachycardia. Cardiol Clin. 1997;15:587-97. [PMID: 0009403162]

78. **Klein GJ, Sharma AD, Yee R.** An approach to therapy for paroxysmal supraventricular tachycardia. Am J Cardiol. 1988;61:77A-82A. [PMID: 0003276127]

79. **Pritchett EL, Anderson JL.** Antiarrhythmic strategies for the chronic management of supraventricular tachycardias. Am J Cardiol. 1988;62:1D-2D. [PMID: 0002900603]

80. **Owens DK, Sox HC.** Medical decision making: probabilistic medical reasoning. In: Shortliffe EH, Perreault LE, Fagan LM, Wiederhold G, eds. Medical Informatics: Computer Applications in Health Care. Reading, MA: Addison-Wesley; 1990:70-116.

81. Statistical Abstract of the United States: 1996. 116th ed. Washington, D.C.: U.S. Bureau of the Census; 1996.

82. National Physician Fee Schedule Relative Value File. www.hcfa.gov/stats/.

83. Gross Domestic Product Deflator Inflation Calculator. www.jsc.nasa.gov/bu2/inflateGDP.html.

84. **Mankiw NG.** Principles of Economics. 2nd ed. Orlando, FL: Harcourt College Publishers; 2001:519.

85. **Eddy DM.** Screening for breast cancer. Ann Intern Med. 1989;111:389-99. [PMID: 0002504094]

86. **Eddy DM.** Screening for cervical cancer. Ann Intern Med. 1990;113:214-26. [PMID: 0002115753]

87. **van Wijck EE, Bosch JL, Hunink MG.** Time-tradeoff values and standard-gamble utilities assessed during telephone interviews versus face-to-face interviews. Med Decis Making. 1998;18:400-5. [PMID: 0010372582]