Introducción

Las taquicardias supraventriculares (TSV) constituyen un grupo de alteraciones del ritmo del corazón que presentan en la población de países menos desarrollados una alta prevalencia. En países como Guatemala, donde la economía es de tipo emergente, la taquicardia supraventricular (TSV) puede ser un problema de salud pública debido a la falta de infraestructura médica adecuada para su tratamiento. El objetivo de este estudio es evaluar la eficacia y la eficiencia económica de la ablación por radiofrecuencia (RFA) en el tratamiento de la TSV en Guatemala.

Métodos: Se realizó un estudio retrospectivo que incluyó a todos los pacientes que recibieron ablación por radiofrecuencia en el Centro de Cardiología del adulto de la Universidad Nacional de Cirugía Cardiovascular (UNICAR) entre 2007 y 2012. Se recogieron datos sobre el número de procedimientos, la tasa de éxito y el tiempo de seguimiento. Se realizó un análisis de coste-efectividad utilizando el modelo de coste de vida ajustada por calidad (QALY) y la técnica de árbol de decisiones.

Resultados: Se llevaron a cabo 103 procedimientos de ablación por radiofrecuencia, con una tasa de éxito del 83% en el primer intento. El coste promedio del procedimiento fue de US$5,411, con un incremento de 1,46 QALY. El análisis de coste-efectividad mostró que la RFA es altamente coste-efectiva en comparación con el tratamiento médico habitual, y se estimó un ahorro de US$7,993 por paciente con TSV en relación con el tratamiento médico habitual.

Conclusiones: La ablación por radiofrecuencia es una alternativa altamente coste-efectiva en el tratamiento de la taquicardia supraventricular en Guatemala. La utilización de diferentes parámetros en el análisis de coste-efectividad mostró que este resultado puede ser aplicable a otros entornos similares.

Keywords: taquicardia supraventricular, ablación por radiofrecuencia, coste-efectividad.

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http://dx.doi.org/10.1016/j.vhri.2015.06.002
Previous studies [7,8] have used decision modeling to show that in patients with SVT who are highly symptomatic or have monthly episodes of arrhythmia, RFA is more effective and less expensive than long-term drug therapy. In addition, ablation improved quality-adjusted life-years (QALYs) by 3.1 years and reduced expenses by US $27,900. However, these studies are several decades old and focused on the United States. Although the procedure is highly effective, with success rates more than 90% in some centers, it has a moderate risk of complications and is relatively expensive [3,7,8].

A limitation of these analyses is that data were gathered from major centers of reference, with highly specialized success rates that often do not represent the less experienced centers, which may differ in various degrees. Furthermore, the analysis was carried out considering only one treatment drug, when in clinical practice physicians usually prescribe various drugs with prices very different from each other [7,8]. Therefore, the objectives of this study were to demonstrate the effectiveness of RFA for SVT in an adult population in Guatemala and to analyze its cost-effectiveness when compared with conventional MT.

### Methods

#### Local Health Outcomes for RFA

We performed a retrospective study in which we reviewed the charts of adult patients (older than 18 years) with SVT who live in Guatemala and had undergone an electrophysiology study and RFA from January 2007 to April 2012. Using the data collection instrument, we gathered data on sociodemographic characteristics, diagnosis, ablation performed, health outcomes of the procedure (success and complication rates), number of follow-up visits a year, MT undertaken, and recurrence of the arrhythmia at 5 months and a year after the procedure (Table 1).

A total of 269 patients participating in the electrophysiology study were identified (Fig. 1). Of these patients, 137 were pediatric cases and an additional 29 of the remaining 132 adults were excluded. The final sample was 103 patients. The patients’ demographic characteristics are presented in Table 1.

#### Decision Model Development

Using the available literature and the outcomes and demographic data of the remaining 103 patients, we developed a decision tree using Microsoft Excel 2013. To create the model, we generated a hypothetical group of patients who underwent either MT or RFA. Patients entered a therapy-specific subtree that simulated the probability of success, recurrence of the SVT after the initial treatment, and complication rates. The patients were considered to initiate in one arm of the tree and move forward at the next appointment 1 year later. If the treatment was not successful,
they would move to the next step on treatment (either adding new medication or undergoing RFA). By the end of the second year of the model, patients were considered stable in the treatment category they remained and the costs were calculated on the basis of this (Fig. 2).

We used the local data of the RFA procedure, when possible, to include the probability of occurrence, complications, cost, and quality of life associated with that outcome. If the probability for an event in the model was not observed in local outcomes (e.g., mortality), it was extrapolated from the published literature (Table 2), mainly from the studies of Hogenhuis et al. [7], Cheng et al. [8], Calkins et al. [9], Ikeda et al. [10], and Bathina et al. [11].

Utilities were primarily extrapolated from values used by Cheng et al. [8] and Larson et al. [12] in their analyses. Larson et al. [12] obtained the utility retrospectively by evaluating highly symptomatic patients with SVT, so we considered it to be the best data for the utilities in our analysis. We assumed that the complications of hemodynamic instability, major bleeding, and vascular injury were transient and were considered resolved before the discharge. Patients who were assumed to get complete heart block had quality of life associated with pacemaker placement.

We considered a 35-year time frame because that is our sample’s average age subtracted from Guatemala’s life expectancy.

Medical treatment
Patients under drug therapy were assumed to receive a daily dose of propafenone. Although we recognized that more inexpensive drugs might be used in actual practice, our choice for the model was propafenone because most of the patients use this drug in UNICAR. Of every 100 patients in the MT arm, 60% would have a reduction in symptoms with MT [7,8,13–15], 10% would need a second drug for their symptoms to be controlled, and 30% would enter the ablation arm of the model. The episodic drug therapy (pill-on-the-pocket strategy) was not included because it has been proven in previous studies to be inferior to long-term drug therapy for highly symptomatic patients [8]. The adverse effects of medications reduced the quality of life for patients.

We did not include emergency department visits in neither strategy because UNICAR does not offer that service.

Radiofrequency Ablation
We defined RFA as initially successful if the electrophysiologist could not induce an arrhythmia in the laboratory after the RFA. However, some patients in whom RFA is initially successful subsequently experience recurrent SVT, typically in the first few weeks after the procedure [8]. In the model, the patient visited the clinic twice the first year after the procedure to ensure that there was no recurrence. Patients were also switched to the MT arm if the arrhythmia was not ablatable or if the ablation was unsuccessful.

Efficacy and complications
The efficacy and complication rates were extrapolated from outcomes in UNICAR. Of the patients assigned to the RFA arm, 83.48% were presumed to have a successful ablation, 16.49% to have a failed ablation, and 0.03% to have a fatal outcome. Regardless of the ablation success, 1.96% were estimated to have a failed ablation, and 0.03% to have a fatal outcome. We assumed that patients in whom RFA was successful required no further antiarrhythmic medication. The incremental costs for each of the complications are described in the footnote of Table 2. A major bleeding episode was defined as an episode greater than type 3 bleeding in the definition proposed by Meheran et al. [16], including those that required blood
transfusion, had a drop of at least 3 g/dl in the hemoglobin level, cardiac tamponade, intracranial bleeding, or fatal bleeding. Hemodynamic instability was defined as persistent hypotension despite fluid management. If the probability for an event in the model was not observed in the local outcomes (e.g., mortality), it was extrapolated from the published literature (Table 2).
In the case of a nonsuccessful first ablation (16.49% of the RFA arm) 29.41% were estimated to enter MT (4.85% of the total fraction in the RFA arm) and the remainder had a second ablation. A total of 91.67% of the second ablations were successful, leading to a total success rate of 94.15% after two ablations. We assumed that the remainder who failed the second ablation had MT.

Costs
We calculated all the costs on the basis of data from UNICAR’s administration during 2012. The data were provided in the local currency (quetzales), which had a conversion factor of US $1 = 7.8Q in 2012. The basic cost of the RFA was $5411.08, and the costs for each arm of the tree were calculated from this. To calculate the follow-up costs, we assumed two outpatient follow-up visits in the first year and then one outpatient appointment for patients in the RFA arm (except for patients with complete heart block who get two yearly appointments) and two appointments for those in the MT arm. The cost of each appointment was calculated by including the salary of physicians and nurses, the cost of one electrocardiogram, and the cost of transport of the patient to UNICAR. We estimated an annual inflation rate of 6%, using the average inflation rate in the last 20 years in Guatemala. The costs were discounted at a 12% nominal discount rate per year (6% real discount rate) because in the context of Guatemala that is a conservative rate. The discount and inflation rates were tested in sensitivity analysis.

Cost-Effectiveness Analysis
Therapies for non–life-threatening SVT by definition affect quality of life rather than length of life [8]. Because of this, we used QALYs to measure the effect of our model.

In this methodology, different states of health can be associated with differences in quality of life (utilities). The 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 health state bothers patients rather than describing the health state in terms of what patients can do. We assigned a “quality of life” for each state of health in the decision tree to reflect those utilities for each possible outcome [7,16]. Patients remaining in the well state for 1 year (utility of 1) were credited with one QALY, dead patients were credited with zero QALY, and patients experiencing morbidity accumulated life-years at an intermediate rate.

Discounting
We considered that each patient entering the model would live an additional 35 years, which is the average life expectancy of Guatemalans minus the average age at ablation. We calculated the expenses incurred in those 35 years of each arm of the model and applied the concept of present value of future expenses. More details about discounting are presented in the Appendix in Supplemental Materials found at http://dx.doi.org/10.1016/j.vhri.2015.06.002.

Decision analysis, projections, and sensitivity analysis
We calculated the expected costs and QALYs per patient treated medically or with RFA for SVT. We then calculated the incremental cost-effectiveness ratio for RFA versus MT and calculated the net benefit of each intervention. The net benefit is a dollar value encompassing the financial and health value of the intervention (see details in the Appendix in Supplemental Materials). Finally, we performed one-way and probabilistic sensitivity analyses on the input parameters to determine which variables had the largest impact on the results. The probabilistic sensitivity analysis was conducted with 10,000 iterations using input distributions presented in Appendix Table A.4 in Supplemental Materials found at http://dx.doi.org/10.1016/j.vhri.2015.06.002.

Results

Local Outcomes in UNICAR
Table 1 presents the characteristics of study patients. There was an overall success rate of 83.48% with a first RFA and a cumulative success rate of 94.15% after a second RFA.

Costs
On the basis of data available at UNICAR, we calculated the basic cost of RFA at $5411.08. The details of expenses for each of the arms are explained in the footnote of Table 2. Because of long-term medications, the MT arm had $16,460 in discounted costs over 35 years. Although RFA had higher initial costs and some costs of complications, longer-term costs were lower because patients took fewer medications. The expected 35 year discounted costs of RFA were $8467. Appendix Figure A.1 in Supplemental Materials found at http://dx.doi.org/10.1016/j.vhri.2015.06.002 shows the cumulative average cost of RFA versus MT.

Calculation of QALYs
Patients with successful RFA had improved quality of life. Table 3 presents expected outcomes under MT and RFA. Patients with MT had 13.49 expected discounted QALYs over 35 years, whereas patients with RFA had 14.95 discounted QALYs over the same period. There was a gain of 1.46 QALYs and a saving of $7993 with RFA compared with MT, which represents a saving of $5480 per QALY gained. This demonstrates that RFA dominates MT in the management of SVT.

We calculated the net benefit using the formula described in the Appendix in Supplemental Materials to examine the dollar value of the choice of therapy. This represents how much one might be willing to pay to have RFA instead of MT if one values QALYs at $3478 (per-capita GDP of Guatemala) over a 35-year time frame. If QALYs are valued at that amount, then RFA

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<th>Table 3 – Cost-effectiveness analysis.</th>
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<td><strong>Total QALYs</strong></td>
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ICER, incremental cost-effectiveness ratio; MT, medical treatment; QALY, quality-adjusted life-year; RFA, radiofrequency ablation.
provides $13,066 more in value than does MT including the value of cost savings and health improvement.

We plotted the incremental cost-effectiveness ratio per year to observe the trend of cost-effectiveness in each year after the procedure (see Appendix Fig. A2 in Supplemental Materials found at http://dx.doi.org/10.1016/j.vhri.2015.06.002).

Sensitivity Analysis
In addition to our base-case analyses, we performed one-way and probabilistic sensitivity analyses (see Appendix Table A4 in Supplemental Materials) in which we systematically varied parameters between low and high values [8].

Fig. 3 presents a tornado diagram displaying the results of key one-way sensitivity analyses on the net benefit of RFA compared with MT. The base-case incremental value of RFA over MT is $13,066. Varying individual parameters within 20% (or extreme limits, if 20% was not possible) show the incremental value of RFA over MT in the horizontal bars. The net monetary value varies slightly, but RFA still always has a positive net monetary value over MT.

The probabilistic sensitivity analysis showed that RFA is highly likely to be cost-effective. There is a 78% chance of it being cost saving and a 92% chance of having a cost-effectiveness ratio of less than $3500 per QALY. Cost-effectiveness acceptability curves are shown in Figure A3.

Discussion
In the present study, we used a disease simulation model to project cost and quality-adjusted life expectancy for a population of 35-year-old patients with symptomatic SVT who were treated with either RFA or continued MT. Using assumptions based largely on the outcomes in UNICAR, we found that RFA is highly cost-effective, taking as a reference the guidelines of World Health Organization-CHOosing Interventions that are Cost Effective (<1x GDP per capita) [9,17].

In Guatemala, the mean cost per RFA of SVT was $5411.08, which is cheaper than that reported in other studies from developed nations, such as Australia, Japan, and the United States [4,7,10,17]. Even when including the costs of the second RFA (after an unsuccessful first attempt; 94.2% success rate), the cost still proved to be between 68.4% and 90.3% lower than that reported in other countries [4,7,10,11]. This lower cost is due to the much lower salaries of medical, nursing, and technical personnel in Guatemala. In addition, the use of reutilized material, such as ablation catheters, decreases the overall cost of the procedure by 66% [4].

When compared with the long-term costs of MT, RFA was almost $8000 less expensive. This indicates that our results are congruent with those of previous studies, including one from Guatemala in the pediatric population, showing that RFA dominates MT for the management of SVT, even in different contexts and with different assumptions [3,4,7,8,11-13].

The model we developed predicts that in patients with SVT, RFA yields a quality-adjusted life expectancy greater than that yielded by MT. Our findings support the usual international practice of initially performing RFA in patients with highly symptomatic SVT. This benefit overcomes the low risk of mortality or nonfatal complications during the procedure.

Our analysis confirms the financial benefits of RFA, particularly with long-term follow-up, due to the elimination of antiarrhythmic medications and the avoidance of subsequent intensive care unit and hospital stays for SVT recurrences.

According to our results, RFA proved effective for patients with drug-refractory symptoms as well as frequent arrhythmic episodes requiring medical attention. Appendix Figure A2 in Supplemental Materials shows that RFA becomes cost-effective from the second year (incremental cost-effectiveness ratio <3 times the GDP), highly cost-effective from the fourth year (<the GDP), and cost saving from the seventh year. This is even after considering a second ablation for those in whom it failed the first time and those who develop any complication. RFA remained the dominant strategy even after we performed probabilistic and deterministic sensitivity analysis, even with a decrease of 50% in the cost of medications. This suggests that RFA, especially in low-income countries, should be the most appropriate therapeutic choice, especially in young patients who would otherwise require lifelong MT [11]. RFA is either cost saving or has a cost-effectiveness ratio comparable to that of many commonly accepted therapies for other diseases [7].

Our sensitivity analyses indicate that RFA is likely to be cost saving or cost-effective under a wide range of assumptions. We made several assumptions to produce a tractable model. We used a long-term perspective to consider in more detail the cost and risk associated with the strategies. Prolonged drug therapy leads to both increased expenditures and an increased risk of adverse effects. We also explicitly modeled crossovers between therapies.

RFA is considered a safe procedure. No deaths were included in the second ablation because it has not been found in previous analysis [4] or it has been significantly lower (0.016% [7], 0.05% [11], and 0.001% [18]) than the 0.03% assumed for our model. We acknowledge that resterilization is a suboptimal and unconventional procedure to lower costs despite the fact that our experience shows no increase in complication rates [4].
The high interest rates for loans taken from the banking system and eventual currency devaluation make the 12% discount rate that we used a conservative rate. It is important to realize that most US studies have used a discount rate of 3% because of a more stable economic system in the United States [8].

This model has several limitations. Because our institution does not possess the information needed to calculate the cost of every single medication used in the electrophysiology study, we included the information provided by the UNICAR administration using hypothetical patients who underwent catheter ablation and information about the most commonly prescribed drugs. Because this may not always be the case, costs might be underestimated (even though this would represent <5% of the total cost of the procedure). Another limitation relates to the fact that before patients were referred to our unit they were treated by various cardiologists without a standard antiarrhythmic protocol [4]. Furthermore, we are not including other comorbidities in the 35-year time frame that could have decreased the QALYs of a given patient.

The fact that we did not include emergency department treatment in our model because it is not offered in UNICAR does not necessarily mean that the patient did not require such treatment (and expenditure) in case of a recurrence of the arrhythmia. If MT patients were to require emergency department treatment, RFA could have an even larger increase in expenditures.

Conclusions

Our study found that RFA dominates MT by improving quality of life and reducing expenditures when used to treat patients with severe symptoms. This is a constant finding, even after varying assumptions about efficacy, complication rates, and quality of life of patients after RFA. Although this analysis used data from Guatemala, the robustness of the results to variations in parameter assumptions suggests that the insights from this study may also hold for other low-income countries with similar costs and procedures.

Given our findings, it may be cost-effective to allocate resources in low-income countries to develop facilities specialized in cardiac electrophysiology to treat effectively, definitively, and at lower cost patients with SVT. We recommend continued testing of the cost-effectiveness of high-technology therapies in developing countries and different settings because the different experience of the teams, cultural acceptance, and lower costs can provide results different from those in developed countries.

Acknowledgments

We thank Salvador Cruz, MSc, for his help with the cost analysis and model projections; Carlos Mendoza-Montano, PhD, and Brett Griffiths, PhD, for editorial assistance; and Maximiliano Guerra, MD, for his help in data collection and database entry.

Source of financial support: The study design and data collection was funded by the National Unit of Cardiovascular Surgery (UNICAR). The interpretation of data and analysis reported in this publication was supported by the Fogarty International Center and the National Institute of Aging of the National Institutes of Health (award no. D43 TW009315). The content is solely the responsibility of the authors and does not necessarily represent the official views of UNICAR or the National Institutes of Health.

Supplemental Materials

Supplemental material accompanying this article can be found in the online version as a http://dx.doi.org/10.1016/j.vhri.2015.06.002 or, if a hard copy of article, at www.valueinhealthjournal.com/issues (select volume, issue, and article).

REFERENCES