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The Effectiveness of Transtelephonic Monitoring of Pacemaker Function in Pediatric Patients

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Introduction

Routine follow-up care of pediatric patients with cardiac pacemakers involves regular assessment of pacemaker function. Pacemakers may fail for a variety of reasons including battery failure, rising thresholds, and lead failure. Clues to all of these malfunctions can be detected by telephone transmission from the patient’s own home, a mechanism of follow-up which has been in use since the 1970s.1-4 Each transmission includes an initial short rhythm strip followed by a threshold margin test and finally another rhythm strip demonstrating the magnet rate of the pacemaker system. Pacemaker malfunction may result in abnormalities in any or all of the three components of the transmission. The development of new dysrhythmias may also be detected on the rhythm strip, and although not always an indicator of pacemaker malfunction, these may warrant adjustment of device settings.

Previous studies of transtelephonic monitoring in both adult and pediatric centers have shown it to be both sensitive and specific for the detection of pacemaker dysfunction.2,5 There are, however, the inevitable false negative and false positive results. This system of follow-up is also plagued by problems with patient compliance.6

A telephone transmission system has been in use at the IWK Children’s Heart Centre in Halifax for approximately 25 years. In combination with intermittent outpatient reviews, it is the primary means of follow-up for our pacemaker patients. Our patients are distributed throughout the entire Maritime Canada region, an area of some 134,000 sq km. Many families report some difficulty in reaching our facility due to a variety of travel constraints, and thus a system of follow-up that can take place in the patients’ own homes would seem advantageous.

Our objectives in this study were threefold. The primary intention was to obtain values for the sensitivity and specificity of telephone transmission of pacemaker function in our geographically diverse pediatric population. Secondly, we sought to obtain data on patient compliance with this system of follow-up. Finally, we...
aimed to unearth any predictors of failure of this system.

**Methods**

A retrospective cohort study by chart review was undertaken. The pacemaker charts containing all recorded telephone transmissions of pediatric patients in Maritime Canada in the years 1995 to 2005 inclusive were analyzed. Data was extracted on transmission assessment (problem vs no problem), indication for transmission (routine scheduled, patient symptoms, repeat transmission for clarification), requirement for clinical review and direct interrogation of pacemaker function (and thus a correlation with the transmitted details), requirement for reprogramming or surgical intervention, gender, age of the child and the pacemaker at the time of transmission, underlying diagnosis, distance from IWK Heart Centre (within Halifax Regional Municipality vs outside), pacemaker model, pacing mode, and deviation of the date of transmission from the recommended guidelines (suggesting patient compliance problems).

In order to obtain the sensitivity and specificity of telephone transmission as a diagnostic test, we compared transmission results with details of pacemaker function obtained at the patient’s next clinical review. Two subtypes of failure of the telephone transmission service were incorporated into our final analysis. These were:

1. False positive results (i.e., abnormal transmissions which prompted clinic review at which no pacemaker problems were identified), and
2. False negative results (i.e., pacemaker dysfunction that was not detected by telephone transmission—detected instead at clinic review due to symptoms or at routine clinic review). We have arbitrarily chosen a time period of 1 month from normal transmission to clinical detection of pacemaker dysfunction, as has been used in previous reports.5,6

To obtain a measure of patient compliance, the ratio of actual transmissions to prescribed transmissions was calculated. A transmission was considered noncompliant if it never occurred or occurred late (by more than 4 days during a period when weekly transmissions were prescribed, by more than 2 weeks during a period when monthly transmissions were prescribed, by more than 3 weeks during a period when 2 monthly transmissions were prescribed, or by more than 1 month during a period when 3 monthly transmissions were prescribed). Scheduled times were adjusted to account for intervening outpatient appointments.

To calculate predictors of failure of the transtelephonic monitoring system, a longitudinal data analysis technique was used. Longitudinal analysis is appropriate for datasets in which multiple observations are made on the same subjects at different points in time. It provides a way to account for the correlation that exists between different observations taken on the same subject and permits a generalized application of the results to the whole population. A marginal model was used on our longitudinal dataset and an exchangeable correlation structure was assumed in order to take into account the correlation between observations on the same patient. An exchangeable correlation structure assumes that the correlation between any two observations on the same subject is constant. That is, for an individual child, the correlation between transmission 1 and transmission 2 is the same as the correlation between transmission 1 and transmission 6. For each transmission, the marginal expectation of the response was regressed on a set of possible explanatory variables using a backwards-stepwise procedure. The variables included age, gender, proximity to our center, pacing mode, pacemaker model, time since implantation, year of transmission, and underlying diagnosis. A Wald test ($\chi^2$) was used to assess statistical significance.

In assessing compliance, we used simple logistic regression, counting each patient’s overall compliance as a single outcome. The variables used in the logistic regression included age at initial implantation, gender, proximity to our center and underlying diagnosis.

**Results**

A total of 2,638 transmissions were received from 106 patients (49 males and 57 females) from June 1995 to June 2005 inclusive. The age at transmission ranged from 12 days to 24.4 years, and the time from pacemaker implantation to transmission ranged from 1 day to 11.6 years. A total of 13% of the patients lived locally, and the remaining 87% lived in other communities within Maritime Canada. The indications for transmission included: routine scheduled 2,261 (85.7%), repeat transmission for clarification 330 (12.5%), and patient symptoms 47, (1.8%). Of the 2,638 transmissions, 234 (8.9%) were unable to be assessed due to poor quality of the printout and these were usually repeated. Documentation of transmission details was unable to be located for 49 (1.9% of all transmissions) and these were excluded from the analysis. Of the remaining 653 abnormal transmissions, the problem for the vast majority was failure of the threshold margin test to be seen within the tracing. On only 20 occasions in 10 years did investigation of these
Table I.
Transmission Problems

<table>
<thead>
<tr>
<th>Transmission Problem</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor quality printout</td>
<td>2</td>
</tr>
<tr>
<td>False positive TMT problem</td>
<td>3</td>
</tr>
<tr>
<td>False positive MR problem</td>
<td>1</td>
</tr>
<tr>
<td>False positive rhythm problem</td>
<td>5</td>
</tr>
<tr>
<td>False positive TMT + MR problems</td>
<td>9</td>
</tr>
<tr>
<td>False negative transmissions</td>
<td>5</td>
</tr>
</tbody>
</table>

TMT = threshold margin test; MR = magnet rate.

Potential false negative transmissions included: 2 cases of lead dysfunction diagnosed at scheduled outpatient review or on Holter monitor after normal transmissions 22 and 23 days prior, 2 cases of impending battery depletion after normal transmissions both 11 days prior, and 1 rhythm problem which had a normal transmission 25 days prior. Table I provides a summary of transmission problems.

Fifty-nine cases of pacemaker dysfunction were diagnosed on transmission (true positives) and these included 28 cases of rhythm disturbance, 16 cases with end-of-battery-life indicators and 15 cases of lead dysfunction. These were all reviewed in the inpatient or outpatient setting for confirmation of the abnormality, reprogramming of the pacemaker or surgical intervention as appropriate. The number of true positive transmissions has been recorded as 92 owing to the performance of repeat transmissions to confirm the abnormalities detected.

Sensitivity and specificity can be obtained from Table II. Based on these figures, telephone transmission of pacemaker function, when used as a diagnostic test, had a sensitivity of 94.8% and a specificity of 99.2%. An abnormal transmission had a positive predictive value of 82.1%. The negative predictive value of a normal transmission was 99.9%.

The longitudinal data analysis failed to identify any significant predictors of failure of telephone transmission (Table III).

During the 10 years of the study period, 3,123 transmissions were “prescribed.” 2,407 occurred at the recommended time. A further 231 occurred but were “late,” as previously defined, and the remaining 485 were missed altogether. Overall compliance with individual prescribed transmissions was, therefore, 77%. If “late” transmissions were included, this improved to 84.5%. For the purposes of assessing compliance, patients were considered compliant if they completed 80% or more of their prescribed transmissions. In this framework, 51/109 (46.8%) of our patients were satisfactorily compliant with telephone transmission follow-up, and if late transmissions were included,

Table II.
Accuracy of Telephone Transmission of Pacemaker Function

<table>
<thead>
<tr>
<th>Transmission Results</th>
<th>Abnormal</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacemaker function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td>92 (TP)</td>
<td>5 (FN)</td>
</tr>
<tr>
<td>Normal</td>
<td>20 (FP)</td>
<td>2,472 (TN)</td>
</tr>
</tbody>
</table>

TP = true positive; FN = false negative; FP = false positive; TN = true negative

Table III.
Logistic Regression Coefficients (standard errors) for the Exchangeable Correlation Structure

<table>
<thead>
<tr>
<th>Variable</th>
<th>Marginal Model Coefficient (SE)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>0.33 (0.37)</td>
<td>0.38</td>
</tr>
<tr>
<td>Age at time of transmission (years)</td>
<td>0.004 (0.43)</td>
<td>0.92</td>
</tr>
<tr>
<td>Proximity to Heart Center</td>
<td>−1.47 (0.99)</td>
<td>0.14</td>
</tr>
<tr>
<td>Year of transmission</td>
<td>0.10 (0.08)</td>
<td>0.24</td>
</tr>
<tr>
<td>Time since pacemaker implantation (years)</td>
<td>0.035 (0.06)</td>
<td>0.52</td>
</tr>
<tr>
<td>Ventricular pacing mode</td>
<td>−0.41 (1.0)</td>
<td>0.68</td>
</tr>
<tr>
<td>Dual chamber pacing mode</td>
<td>1.14 (1.11)</td>
<td>0.30</td>
</tr>
<tr>
<td>Single-chamber rate-responsive device</td>
<td>1.03 (1.67)</td>
<td>0.54</td>
</tr>
<tr>
<td>Dual-chamber nonrate-responsive device</td>
<td>0.70 (1.78)</td>
<td>0.70</td>
</tr>
<tr>
<td>Single-chamber nonrate-responsive device</td>
<td>0.99 (1.77)</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Pacing modes were coded as factors and regression coefficients were calculated relative to Atrial pacing modes. Pacemaker models were coded as factors and regression coefficients were calculated relative to Dual-chamber rate-responsive device models.
73/109 (67.0%) could be described as compliant. Logistic regression failed to identify any predictors of poor compliance.

Discussion

Our experience with telephone transmission during the 10 years covered by this study, and indeed in the years prior, has been a positive one. Our impression was that it had been a sensitive and specific tool for the detection of pacemaker dysfunction. The results of this study have supported this clinical impression and closely compare with previously published sensitivities of 95% to 100% and specificity of 98.5%.^5,6^ The high negative predictive value obtained in our study and others^5^ provides support for the continued usage of a telephone transmission system in that the vast majority of assessments of pacemaker function will be normal and will be transmitted as such. A normal transmission should be quite reassuring for patients and their families, as well as for the physicians following them.

Despite the benefits of reassurance, it is obviously important not to miss significant pacemaker dysfunction. Some studies have found that in-office follow-up of pacemaker patients detects more cases of pacemaker dysfunction than transtelephonic follow-up.^7,8^ In fact, the Canadian Working Group on Cardiac Pacing recommends direct patient follow-up rather than transtelephonic monitoring but recognizes that the latter may be more practical in geographically isolated patients and in cases where frequent monitoring is required. These exceptions would certainly apply to many of our study patients. It has therefore been recommended that transtelephonic monitoring only be used as an adjunct to ongoing monitoring rather than as the exclusive means of follow-up, and this has been our practice. In fact, up to 2,229 outpatient visits were avoided by the use of this system over the 10 years of the study period. This is a considerable cost benefit to the health system and to the patient and family, as has been shown by previous studies.^6,9,12,13^ Logitudinal analysis of our failed transmissions revealed no significant predictors of transmission failure. This too is reassuring as there was no difference in accuracy of the transmission service for patients living farther from a tertiary Cardiology center, patients with recently implanted devices or younger patients, nor was there any particular underlying diagnosis that reduced accuracy. Also, there were no differences in ability to transmit with any of the pacemaker models or pacing modes in use by our population.

Compliance with scheduled transmissions in Maritime Canada has been higher than that reported in other studies. The primary reason for this is most likely the telephone follow-up of late transmissions by our technical staff. The provision of a toll-free telephone number since 2004 may also have removed some financial constraints and thus enhanced compliance. It may be that the transmission service itself has improved overall compliance with follow-up as some studies have suggested that follow-up rates of pacemaker patients are actually enhanced by the use of a telephone monitoring system.^14^

Conclusions

Maintaining an awareness of the potential inaccuracies inherent within a telephone transmission service is essential when integrating such a system into follow-up arrangements. While certainly not a perfect tool for follow-up, we believe that the reassurance of a normal transmission and the convenience and cost-savings afforded by this test make it a very useful tool for the follow-up of pediatric pacemaker patients. Families appear to support this view as evidenced by the higher than previously reported compliance rate with prescribed transmissions.

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References


