Supraventricular tachycardia (SVT) is the most common rhythm disturbance in children, with the majority of these being mediated by the presence of an accessory pathway (AP). Catheter-based ablation for SVT is now a well-established treatment modality in this population and is associated with high success rates and low complication rates. Recent advances in electroanatomic mapping and catheter navigation have enhanced our ability to safely and effectively ablate SVT in this population.

Magnetic navigation (MN) is a new and evolving technology, which harbors multiple purported benefits. Early studies in adults have found MN to be safe and effective for ablation of various arrhythmias, including atrial fibrillation, atrial flutter, atrioventricular nodal reentry, and ventricular tachycardia with an apparent decreased need for fluoroscopy. Preliminary evaluation in children and adults with congenital heart disease also found MN to have potential advantages in this specialized cohort without compromising efficacy. Little data exist regarding the use of MN and its potential benefits for ablation of AP-mediated tachycardia in children.

**Background**—Transcatheter ablation of accessory pathway (AP)–mediated tachycardia is routinely performed in children. Little data exist regarding the use of magnetic navigation (MN) and its potential benefits for ablation of AP-mediated tachycardia in this population.

**Methods and Results**—We performed a retrospective review of prospectively gathered data in children undergoing radiofrequency ablation at our institution since the installation of MN (Stereotaxis Inc, St. Louis, MO) in March 2009. The efficacy and safety between an MN-guided approach and standard manual techniques for mapping and ablation of AP-mediated tachycardia were compared. During the 26-month study period, 145 patients underwent radiofrequency ablation for AP-mediated tachycardia. Seventy-three patients were ablated with MN and 72 with a standard manual approach. There were no significant differences in demographic factors between the 2 groups with a mean cohort age of 13.1±4.0 years. Acute success rates were equivalent with 68 of 73 (93.2%) patients in the MN group being successfully ablated versus 68 of 72 (94.4%) patients in the manual group (P=0.889). During a median follow-up of 21.4 months, there were no recurrences in the MN group and 2 recurrences in the manual group (P=0.388). There were no differences in time to effect, number of lesions delivered, or average ablation power. There was also no difference in total procedure time, but fluoroscopy time was significantly reduced in the MN group at 14.0 (interquartile range, 3.8–23.9) minutes compared with the manual group at 28.1 (interquartile range, 15.3–47.3) minutes (P<0.001). There were no complications in either group.

**Conclusions**—MN is a safe and effective approach to ablate AP-mediated tachycardia in children. (Circ Arrhythm Electrophysiol. 2012;5:804-808.)

**Key Words:** ablation ■ arrhythmia (heart rhythm disorders) ■ mapping ■ pediatrics

**Clinical Perspective on p 808**

In this cohort study, data were collected prospectively into an ongoing ablation registry on all children undergoing radiofrequency (RF) ablation for AP-mediated tachycardia at our institution since MN was introduced in our hospital. Patients older than the age of 18 years or with associated congenital heart disease or previous ablations were excluded. Parahisian pathways and septal pathways where cryoablation was used were also excluded. All procedures were performed at Texas Children’s Hospital and spanned the period from March 2009 to May 2011, inclusively. The study was approved by the Baylor College of Medicine Institutional Review Board. Data collected included patient demographics, clinical arrhythmia characteristics including AP location, procedural techniques, ablation characteristics, procedure and fluoroscopy times, outcomes, and complications. The primary outcomes evaluated were acute success rate, recurrence rate, and complications. Acute success was defined as complete elimination of AP
conduction, as well as inducible tachycardia. Recurrence was defined as any evidence of return of AP conduction or recurrence of SVT.

All practitioners using the MN system for mapping and ablation underwent formal training and orientation at the Stereotaxis Inc (St. Louis, MO) training facility and were subsequently proctored for at the minimum of 1 case. All subsequent cases were included in the analysis. During the study period, ablations using RF were alternated between MN (Stereotaxis Inc) and standard manual navigation. This was done to ensure an equal distribution of cases during the same period without selection bias and to guarantee that the training fellows at our institution received adequate hands-on time for manual catheter manipulation. There was no designated crossover for cases, when initial ablation was unsuccessful and subsequent transition in navigation methods or use of alternative catheters in such cases was left up to the decision of the practitioner. Any crossover or transition in modality was considered an acute failure. A 3-dimensional electroanatomic activation map (CARTO XP; Biosense Webster, Diamond Bar, CA) was constructed for each case, which has become standard practice in our institution. Manual RF ablation was performed using a 4-mm tip EZ Steer Nav catheter (Biosense Webster), and MN RF ablation was performed using a 4-mm tip Navistar RMT catheter (Biosense Webster). All ablations were performed in a temperature control mode (maximum temperature, 65°C; maximum duration, 60 seconds; maximum energy, 50 W) using a Stockert RF Generator (Biosense Webster). All left-sided ablations were performed via a transseptal approach because of institutional practice. The efficacy between an MN-guided approach and standard manual techniques was then compared. Complications during and after the procedure were recorded.

The data are presented as patient-specific and ablation-specific variables. Continuous variables are presented as mean with SDs or medians with interquartile ranges, depending on the normality of their distribution. Categorical variables are presented as counts and percentages. The 2-sample t test and the Wilcoxon rank sum test were used for normally and nonnormally distributed data, respectively. The Fisher exact test or the χ² test was used for categorical data. Log-rank test was used to analyze time-stratified events. The level of significance was set at P<0.05. All statistical analyses were performed using SPSS version 18.0 for Windows (SPSS Inc, Chicago, IL).

Results

During the 26-month study period, 145 patients underwent RF ablation for AP-mediated tachycardia at our institution. Seventy-three patients were ablated with MN and 72 with a standard manual approach. There were no significant differences in demographic factors between the 2 groups with a total mean age of 13.1±4.0 years and a total mean weight of 49.9±19.8 kg (Table). Acute success rates were equivalent, with 68 of 73 (93.2%) patients in the MN group being successfully ablated versus 68 of 72 (94.4%) patients in the manual group (P=0.889). In 4 patients in whom there was initial failure with MN, there was crossover to attempts at ablation with manual navigation during the case. In 3 of these 4 cases, a standard manual approach was also unsuccessful in achieving the elimination of AP conduction. In 1 case, transition to a manual approach did result in acute success. No common variables were identified in the failed ablations to suggest causative pathogenesis. None of the failed ablations with a standard manual approach were transitioned to attempts with MN. This was because of operator preference, which may have been affected by the additional setup time required to switch to the MN system.

During a median follow-up of 21.4 (interquartile range, 13.0–27.7) months, there were no recurrences in the MN group and 2 recurrences in the manual group (P=0.388). One of the recurrences occurred within 1 month after the ablation and was thought to be because of catheter instability during lesion placement at the time of the initial procedure. This patient was brought back for a repeat ablation with the MN system, and AP conduction was successfully ablated with reported improved catheter stability. There has been no further recurrence in >6 months.

There were no differences between the 2 groups in regard to AP location, time to effect, number of lesions delivered, or average ablation power (Table). There was a small difference in average ablation temperature, with a mean in the MN group of 47.9°C and a mean in the manual group of 51.8°C (P=0.040). There was also no difference in total procedure time between the 2 groups (Table). Fluoroscopy time, however, was significantly reduced in the MN group at 14.0 (interquartile range, 3.8–23.9) minutes compared with the manual

Table. Patient Characteristics and Procedural Outcome Comparisons Between Methods of Navigation

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (n=145)</th>
<th>MN (n=73)</th>
<th>Manual Navigation (n=72)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>13.1 (4.0)</td>
<td>13.1 (4.0)</td>
<td>13.0 (3.9)</td>
<td>0.908</td>
</tr>
<tr>
<td>Sex, female (%)</td>
<td>60 (41)</td>
<td>31 (42)</td>
<td>29 (40)</td>
<td>0.474</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>52.2 (20.0)</td>
<td>50.9 (19.4)</td>
<td>54.1 (20.9)</td>
<td>0.426</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.4 (0.4)</td>
<td>1.4 (0.3)</td>
<td>1.5 (0.4)</td>
<td>0.780</td>
</tr>
<tr>
<td>AP sidedness, left (%)</td>
<td>97 (67)</td>
<td>51 (69)</td>
<td>46 (64)</td>
<td>0.162</td>
</tr>
<tr>
<td>Acute success (%)</td>
<td>136 (94)</td>
<td>68 (93)</td>
<td>68 (94)</td>
<td>0.889</td>
</tr>
<tr>
<td>Time to effect, sec</td>
<td>4.4 (2.4)</td>
<td>4.1 (2.4)</td>
<td>4.8 (2.3)</td>
<td>0.242</td>
</tr>
<tr>
<td>Average temperature, °C</td>
<td>49.5 (5.9)</td>
<td>47.9 (6.3)</td>
<td>51.8 (5.5)</td>
<td>0.040</td>
</tr>
<tr>
<td>Procedure time, min</td>
<td>226.5 (192.0–287.3)</td>
<td>226.0 (201.0–269.9)</td>
<td>226.4 (185.7–312.7)</td>
<td>0.904</td>
</tr>
</tbody>
</table>

MN indicates magnetic navigation; BSA, body surface area; and AP, accessory pathway.

*Comparing MN with manual navigation.
group at 28.1 minutes (interquartile range, 15.3–47.3 minutes; \(P<0.001\)).

There were no major or minor complications in either group, including bleeding, infection, cardiac perforation, pericardial effusion, stroke, atrioventricular block, or death. A few procedural impediments were noted with technical aspects of MN, however. In 3 cases in which transseptal procedures were performed for left-sided mapping, the middle magnet on the Navistar RMT catheter (Figure) became stuck in the septum, requiring withdrawal and remanipulation of the catheter or advancement of a long sheath through the septum. Also, in 1 child (24 kg) in whom a sheath was placed in the right internal jugular vein for additional access, the handle of a steerable decapolar catheter (Biosense Webster), which was positioned in the coronary sinus, was attracted to the external steering magnets (Niobe system, Stereotaxis Inc) and pulled out of the sheath, resulting in a loss of catheter positioning. None of these technical issues resulted in ablation failure, complications, or significant prolongation of the case.

**Discussion**

Recent advances in mapping technologies and navigation techniques have resulted in improved safety and efficacy profiles in many populations. Most recently, the ability to navigate ablation catheters with remote control systems has evolved and has been met with much enthusiasm, although the impact of these techniques on practice is not yet clear.\(^6,11,12\) Early studies in adults using remote MN for ablation of various types of arrhythmias have been promising with improved safety and equivalent efficacy profiles compared with standard manual techniques.\(^6,11,12\) In children, data remain limited. An initial report by Schwagten et al\(^6\) in a series of children and adults with complex congenital heart disease found that RF ablation using MN for arrhythmias in this cohort was safe and effective. A subsequent study in a small cohort of children with supraventricular arrhythmias of all types suggested that the use of MN for treatment in this group could be advantageous because of reduced procedure and fluoroscopy times.\(^7\) The specific use of MN and its potential benefits for ablation of standard AP-mediated tachycardia in children have not been well described.

MN does offer some theoretic advantages in the treatment of children. The MN catheter is more flexible and atraumatic than standard catheters, potentially eliminating any risk of perforation. It can also be navigated with precision, allowing for movements as small as 1 mm or deflections as small as 1°, while making several consecutive bends in different directions. This may obviate the need for attempts with multiple catheters and sheaths with different curvatures. At the same time, the catheter is stable once positioned, being held by a constant magnetic field rather than by manual torque. These characteristics promote the hypothesis that MN may enhance accuracy and safety during the mapping and ablation of certain arrhythmias in this population.

The results of the present study demonstrate that MN can, indeed, be safely and effectively used for RF ablation of AP-mediated tachycardia in children. Acute success and recurrence rates were similar to standard manual navigation techniques, and the results were in line with the present published benchmarks.\(^3\) Surrogate measures of accuracy, such as time to effect and number of lesions required, also revealed no difference between the groups. The average ablation temperature was lower in the MN group in comparison with the manual navigation group, which may be related to a difference in contact and orientation of the catheter during lesion placement. This discrepancy did not, however, alter acute success or recurrence rates with midterm follow-up (average, 14 months).

In our cohort, although total procedure times were unaffected, fluoroscopy times were dramatically reduced in cases using MN. This is similar to early findings in larger adult studies evaluating the use of MN in other forms of arrhythmias.\(^6,12\) In our study, the reason for reduced fluoroscopy times with MN is not entirely clear because both navigation methodologies did incorporate 3-dimensional mapping. In our institution, however, this may have been partially related to active fellowship training. In cases with manual navigation, catheter manipulation and fluoroscopy were under control of the fellow in training, whereas in cases using MN, catheter guidance and fluoroscopy were under the control of the attending physician. Therefore, a difference in experience between the primary catheter operators may have played a role in the discrepancy in times. It should also be stated that although the fluoroscopy times for manual navigation techniques reported in the present study are in line with published benchmarks,\(^4\) recent attempts at reducing fluoroscopy in pediatric ablations with present mapping systems have had dramatic effects, and the gold standard regardless of navigation technique should

**Figure.** Fluoroscopy demonstrating the middle magnet on the Navistar RMT catheter stuck in the atrial septum, which required withdrawal and remanipulation of the catheter with advancement of a long sheath. A corresponding image demonstrates the increase in girth at the middle magnet from 7F to 8F in diameter.
perhaps be aimed significantly lower. In our institution, use of a 3-dimensional mapping system to allow for decreased fluoroscopy regardless of navigation technique has become standard care. Regardless of the primary reason, however, reduced fluoroscopy times remain important to consider because any reduction in radiation exposure in young children may have lasting effects.

It should also be emphasized that radiation exposure to the ablationist in cases using MN is nominal by design, because the practitioner sits outside the field of exposure. This should not be understated considering the lifetime exposure a practitioner may receive. In this same light, the ability to perform a procedure while sitting in a control room without bearing the weight of heavy personal protective apparel may have long-standing implications. Data now strongly indicate that working in the interventional laboratory overtime is associated with occupational health risks, including orthopedic problems frequently related to the spine. These occupational injuries can result in chronic pain and, in some instances, even curtail interventional careers. A system that enhances the comfort, health, and longevity of the physician while maintaining established standards in efficacy and safety may have advantages outside the realm of immediate patient care.

Although there were no complications in our experience, a few procedural nuances were encountered and should be noted. First, the positional magnets on the Navistar RMT catheter have a slight increase in diameter (7F–8F), particularly at the middle magnet. This accompanied with the floppiness of the proximal shaft of the catheter can impede free manipulation through the septum after transseptal access is obtained. Therefore, it may be warranted to maintain long sheath positioning across the septum during mapping and ablation. Second, access from the neck in smaller children can be in close proximity to the navigational external steering magnets, and therefore, catheters inserted from this position must be secured or confirmed to have no ferrous material in the handle to avoid inadvertent dislodgement during the procedure. Last, the conceptual approach to catheter navigation and positioning with MN is different from the standard manual approach in the sense that the catheter is pulled and held in location by a magnetic field rather than pushed, deflected, and rotated into position. As such, there is decreased tensile strength, and rotational torque around structures such as prominent eustachian valves may be more difficult. Alternatively, the ability to maintain a position may prove valuable in areas where catheter stability has previously proven problematic. In at least 1 case in our cohort, lack of catheter stability during ablation with a manual catheter was associated with recurrence. Subsequent ablation with MN resulted in improved catheter stability during ablation with improved success.

Finally, although a cost analysis of MN is outside the scope of the present study, it should be stated that financial implications may play a role in its use. There is a requisite initial investment for installation, as well as continued costs for peripherals and catheters. Further cost analysis may be warranted.

There are a few limitations to the present study, First, there was no true account for a learning curve with MN. As such, the results with MN may ultimately be proven better than reported in the present study, because one would expect the outcomes to get better with experience. Second, because our institution continues to emphasize fellow training and education, particularly in regard to manual catheter manipulation, some results may be affected by experience discrepancies between modalities. It is possible that the outcomes with manual navigation are thus understated, although they are in line with previously published reports. Last, given the low rates of failure and recurrence for ablation of SVT in children, statistical power for comparison between groups remains limited in many regards. Clearly, further study is warranted regarding the potential benefits of MN in this population.

Conclusions
MN is a safe and effective approach to ablate AP-mediated tachycardia in children. Fluoroscopy times compare favorably with manual navigation techniques, and of equal importance, long-term radiation exposure for the ablationist is nominal by design. MN should, therefore, be considered an evolving tool in the armamentarium for the pediatric ablationist. The potential benefits in more complex populations remain to be elucidated.

Disclosures
None.

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**CLINICAL PERSPECTIVE**
Catheter ablation for supraventricular tachycardia is now a well-established treatment modality in children. Recent advances
in electroanatomic mapping and catheter navigation have enhanced our capability to map and ablate arrhythmias in this pop-
ulation. Little data exist regarding the use of magnetic navigation for ablation of accessory pathway–mediated tachycardia in
children. We report a single-center cohort study with retrospective review of prospectively collected data on all patients who
underwent radiofrequency ablation of accessory pathways at our institution since magnetic navigation was introduced. The
efficacy and safety between a magnetically guided approach and standard manual techniques for mapping and ablation were
compared. Acute success rates were equivalent between the 2 groups, and recurrence rates were also similar. There was no
difference in total procedure time, but mean fluoroscopy time was significantly reduced in the magnetic navigation group at
14 minutes compared with 28 minutes in the manual ablation group. There were no complications observed in either group.
This is the first study demonstrating that magnetic navigation appears to be a safe and effective approach to ablate accessory
pathway-mediated tachycardia in children.