
1. Introduction

Approximately 180 leading global hospitals have adopted the Niobe® Magnetic Navigation System (MNS) for EP ablation. The current Niobe MNS is a 4th Generation system, an evolution from earlier Stereotaxis clinical systems. To date, over 80,000 EP procedures have been performed with magnetic navigation. Of the estimated 280 total peer-reviewed scientific publications highlighting remote magnetic navigation technology listed in Stereotaxis’ PRO-240, more than 85% of the publications discuss its use in cardiac EP procedures and are featured in peer-reviewed journals such as the Journal of Cardiovascular Electrophysiology, PACE, Europace, the Journal of American College of Cardiology, and the Journal of Interventional Cardiac Electrophysiology. This body of clinical research, resulting journal publications and physician advocacy has led to greater market access, regulatory and reimbursement support, and provider adoption.

This peer-reviewed published research with Stereotaxis’ innovative technologies and published papers have established overwhelming evidence supporting magnetic navigation’s clinical benefits, including:

- Improving long-term patient clinical outcomes (atrial fibrillation [AF], ventricular tachycardia [VT], and congenital heart disease treatment)
- Continued improvements in procedural efficiency through reduced treatment times and improved patient work flow when compared to older Niobe systems
- Excellent patient safety due to the flexible catheter shaft
- Low X-ray fluoroscopic radiation for physicians, laboratory staff and patients (especially for the vulnerable pediatric population)

The following is a review of the literature up to December 2016 and includes a series of recent publications and presented abstracts that support these advantages.

2. Clinical Evidence Summary

- Improved AF Outcomes and Efficiency

Magnetic navigation has been widely used for AF ablation with strong reported clinical outcomes (acute and chronic), significantly less radiation exposure and improved safety profiles in comparison to previously published manual ablation procedures. Magnetic stable focal contact of the catheter and the subsequent lesion formation may be the underlying reason for reported improving trends for those clinical advantages.

This hypothesis was tested using a myocardial phantom model. Bhaskaran et al. demonstrated that the use of magnetic navigation of the catheter provided greater catheter
stability than manual navigation, resulting in deeper lesions.(1) Stable focal contact and
deeper lesion formation may be contributing factors to the observed trends in higher

A recent clinical study conducted by the Princess Grace Hospital of Monaco
demonstrated positive findings in the remote magnetic navigation platform's success in
treating AF cases.(2) This study of 90 consecutive patients compared the acute success
and recurrence rates in two patients groups that were given the choice to be either
administered general anesthesia or local anesthesia. All patients underwent the
Stereotaxis magnetic navigation ablation procedure for symptomatic paroxysmal/
persistent AF.

Both groups experienced 100% acute success rates. After 12 months of
follow-up, and inclusion of repeat procedures, the general anesthesia group was 86.6%
free from any arrhythmias without using antiarrhythmic drugs, compared to 88.8% for the
local anesthesia group.

Jin et al. analyzed data from over 1000 AF procedures from Rigshospitalet, Copenhagen
University Hospital.(3) The objectives were to evaluate peri-procedural complications,
assess procedural outcomes and compare procedural outcomes between patients
undergoing first and repeat ablation procedures. Total complication rates for the 1006
procedures were 0.6%. Fluoroscopy time for the 726 patients was 5.4 ± 3.7 min with total
procedure times lasting 134 ± 35 mins. Overall repeat procedures for these 726 patients
were 33% with the time since initial ablation being 17.5 ± 9.8 months.

Most recently, Da Costa et al. compared procedural efficiency times of the *Niobe* II and
the *Niobe* ES systems.(4) They analyzed procedural parameters of 92 consecutive
patients in each group. This study demonstrated that the 4th generation system, *Niobe* ES,
significantly reduced total procedure time by 30% and fluoroscopy time by 30% when
compared to the older *Niobe* II system, which further supports continued improvements
in efficiency and work flow.
• Improved VT Ablation Outcomes

Magnetic navigation provides significant advantages in VT ablation due to its catheter tip’s unique omni-directional flexibility. This flexibility along with magnetic stable focal contact are key reasons that magnetic navigation has been repeatedly shown to be more effective than manual pull-wire catheter technologies. This gives remote magnetic navigation a distinct advantage in VT ablation, since the catheter often needs to create deep lesions in challenging anatomical areas within diseased ventricular chambers. Many Stereotaxis magnetic navigation users believe that they can achieve much better results in VT ablation using magnetic navigation across all clinical endpoints (including acute success, long-term outcome, procedure time, safety, and X-ray fluoroscopic time) as described with the following reported studies:

Szili-Torok et al. studied 72 patients who underwent MNS guidance for VT ablation vs. 41 patients with manual (MAN) VT ablation.(5) The authors reported significant benefits using MNS in VT ablation (acute success, procedure time, X-ray fluoroscopy time, safety, and 20-month chronic success):

Bauernfeind et al. also reported significantly improved acute VT success rate and fluoroscopy times when using MNS:(6)
Adapted data from Bauernfeind et al. 2011

Di Biase et al. presented a poster at 2015 American Heart Association Scientific Sessions also reporting that RMN has significantly better long-term success rates than manual navigation when ablating ventricular arrhythmias, particularly those caused by large ventricular scar (scar size greater than 60 cm$^2$):(7)

Hendriks et al. from the Erasmus Medical Center in the Netherlands recently released the results of a study comparing the success of VT ablation procedures using manual, magnetic, and contact force (CF) catheters.(8) Only 1.2% of RMN patients experienced major complications during the ablation procedure, compared with 2.7% of MAN patients and 10.0% of CF patients. After a median follow-up period of 25 months, the Kaplan-Meier analysis showed that the RMN group had the lowest rate of VT recurrence at 42%, compared to 59% for the MAN group and 57% for the CF group.

Adapted and Original data from Hendriks et al. 2015

Adapted data from Di Biase et al. 2015
Lastly, Skoda et al. evaluated MNS mapping and ablation of post infarction VT in a multicenter, prospective single-arm study (STOP-VT Trial). They reported no procedural complications and very favorable acute and 12 month follow-up success rates: (9)

<table>
<thead>
<tr>
<th>Mean procedure time</th>
<th>220 minutes</th>
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<tbody>
<tr>
<td>Mean fluoroscopy time</td>
<td>8.7 minutes</td>
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<tr>
<td>Mean fluoroscopy time during mapping and ablation</td>
<td>0.95 minutes</td>
</tr>
<tr>
<td>Mean RF time</td>
<td>38 minutes</td>
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<tr>
<td>Procedural Complications</td>
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</tbody>
</table>

![Success Rates](image)

Adapted data from Skoda et al 2016

- **Improved EP Ablation for Pediatric Patients**

Pediatric patients are highly vulnerable to harmful X-ray radiation exposure, as physician scientists believe that children exposed to X-ray radiation have a 4 fold increase in developing cancer at a later stage in these children’s lives.(10) Magnetic navigation has improved upon manual catheter results by achieving the same treatment outcome while reducing X-ray radiation exposure.

Kim et al. studied the use of magnetic navigation (MN) in ablation of children (n=73 using RMN technology, and n=72 using MAN procedure), and reported that magnetic navigation can deliver the same treatment outcome while reducing the X-ray radiation time by 50%.(11)

Schwagten et al. studied 58 pediatric patients that were less than 10 yrs in age (n=29 for ablation with RMN, and n=29 for MAN ablation). The authors concluded their data strongly suggest that using the MNS for treating young children is advantageous, because it significantly reduced the procedure and fluoroscopy times without compromising efficacy(12)

Most recently, PACES/HRS published an Expert Consensus Statement on the Use of Catheter Ablation in Children and Patients with Congenital Heart Disease giving a Class IIb recommendation for using RMN as a procedural consideration when navigating through complex anatomies and retrograde approaches and reducing fluoroscopy times. They stated that a remote magnetic navigation system might be reasonable for catheter ablation of tachyarrhythmias in complex CHD with difficult intracardiac anatomy or vascular access. (13)
- Improved EP Ablation for Patients with Congenital Heart Diseases (CHD)

CHD patients are among the most challenging group for manual EP treatment, due to abnormal anatomy in these patients’ heart chambers. Magnetic navigation presents unique advantages in EP treatment for CHD patients, as it helps surmount three major challenges: limited access to the target chamber, extensive atrial enlargement, and/or extensive wall thickness.

Ueda et al. published the largest CHD-related study to date using magnetic navigation in ablation treatment of SVT in CHD patients (n=116).(14) There were three groups of patients, with varying degree of pathologies for each group (progressively more challenging pathologies for RMN). Fluoroscopy times were lower in the 2 RMN groups (median ranges 4-6 minutes) versus 8 minutes in the manual procedure group. The less complex cases performed with manual ablation demonstrated an approximate 90% acute success and in the more complex set of patients treated with RMN, acute success was over 80% in both RMN groups. The authors reported increasing trends in 20-month success rate (long-term) for RMN (82%) vs. manual ablation (80%). This is an important finding given the more difficult cases targeted with RMN.

Schwagten et al. studied 12 CHD patients who underwent ablation for supraventricular tachycardia (& congenital heart disease) with magnetic navigation.(15) The authors reported favorable results for magnetic navigation procedure time, fluoroscopy time and complication rates. They concluded that using RMN for congenital heart disease is safe and effective.

- Improved Patient Safety and Reduced X-Ray Fluoroscopic Radiation

The flexible ablation catheters designed for Stereotaxis’ remote magnetic navigation systems offers a much safer ablation procedure. The magnetic field that guides these catheters with a level of precision has led to few complications as well as significantly reduced X-ray radiation exposure for both physicians and patients as supported by Bauernfeind et al. (6)

In summary, as the Niobe ES system continues to be enhanced and users become more proficient, complication rates, average procedure times, and average fluoroscopy times will continue to improve.(16) Additionally, the robotic technology improves the efficiency of challenging VT cases by optimizing procedural workflows and reducing procedure time variability.(17) These improvements will potentially reduce occupational risks associated with the manual ablation procedure. RMN exposes physicians and laboratory staff to less radiation and relieves them of the orthopedic burden of wearing lead aprons. Much more of the direct clinical proof demonstrating magnetic navigation’s clinical benefits will come from future perspective, multi-center, randomized controlled clinical studies.
Stereotaxis Intended Use Statements
United States Labeling

The Niobe ES system is intended to navigate compatible magnetic devices through tissue to designated target sites in the right and left heart and coronary vasculature and peripheral vasculature by orienting the device tip in a desired direction.

The Stereotaxis Cardiodrive automated catheter advancement system (CAS) is intended for automatically advancing and retracting only compatible magnetic electrophysiology (EP) mapping and ablation catheters inside the patient’s heart when used in conjunction with a Stereotaxis MNS. The Cardiodrive system is not intended to advance the EP mapping and ablation catheters through the coronary vasculature or the coronary sinus.

Consult the associated product labeling for the Indications for Use and instructions of other devices used in conjunction with Stereotaxis products.

Bibliography


