

# The magnetic navigation system allows safety and high efficacy for ablation of arrhythmias

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## Aims

We aimed to evaluate the safety and long-term efficacy of the magnetic navigation system (MNS) in a large number of patients. The MNS has the potential for improving safety and efficacy based on atraumatic catheter design and superior navigation capabilities.

## Methods and results

In this study, 610 consecutive patients underwent ablation. Patients were divided into two age- and sex-matched groups. Ablations were performed either using MNS (group MNS, 292) or conventional manual ablation [group manual navigation (MAN), 318]. The following parameters were analysed: acute success rate, fluoroscopy time, procedure time, complications [major: pericardial tamponade, permanent atrioventricular (AV) block, major bleeding, and death; minor: minor bleeding and temporary AV block]. Recurrence rate was assessed during follow-up ( $15 \pm 9.5$  months). Subgroup analysis was performed for the following groups: atrial fibrillation, isthmus dependent and atypical atrial flutter, atrial tachycardia, AV nodal re-entrant tachycardia, circus movement tachycardia, and ventricular tachycardia (VT). Magnetic navigation system was associated with less major complications (0.34 vs. 3.2%,  $P = 0.01$ ). The total numbers of complications were lower in group MNS (4.5 vs. 10%,  $P = 0.005$ ). Magnetic navigation system was equally effective as MAN in acute success rate for overall groups (92 vs. 94%,  $P = \text{ns}$ ). Magnetic navigation system was more successful for VTs (93 vs. 72%,  $P < 0.05$ ). Less fluoroscopy was used in group MNS ( $30 \pm 20$  vs.  $35 \pm 25$  min,  $P < 0.01$ ). There were no differences in procedure times and recurrence rates for the overall groups ( $168 \pm 67$  vs.  $159 \pm 75$  min,  $P = \text{ns}$ ; 14 vs. 11%,  $P = \text{ns}$ ; respectively).

## Conclusions

Our data suggest that the use of MNS improves safety without compromising efficiency of ablations. Magnetic navigation system is more effective than manual ablation for VTs.

## Keywords

Arrhythmias • Catheter ablation • Remote magnetic navigation

## Introduction

Catheter ablation was introduced in clinical electrophysiology (EP) in the 1980s.<sup>1,2</sup> In past decades, it became well established as first-line therapy for many types of arrhythmias, including atrioventricular (AV) nodal re-entrant tachycardia (AVNRT), circus movement tachycardia (CMT), and cavotricuspid isthmus (CTI)-dependent atrial flutter (AFL), and as therapeutic option for the treatment of atrial fibrillation (AFib), atrial tachycardia (AT), and ventricular

tachycardia (VT).<sup>3</sup> Further developments were implemented such as electroanatomical mapping, integration of cardiac imaging, and improved catheter design.<sup>4,5</sup> Until recently, all of the above-mentioned techniques were based on manual catheter navigation in the heart. The innovation of the remote magnetic navigation system (MNS) offered important theoretical advantages in safety due to the atraumatic catheter design and less physical stress and radiation exposure for the physician.<sup>6–11</sup> Higher efficacy is also expected due to the unrestricted and reproducible catheter

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movement, and improved catheter stability.<sup>8,11–13</sup> Numerous centres reported their initial experiences with MNS confirming its feasibility for ablation of most arrhythmias.<sup>14–23</sup> However, these early reports included only small numbers of patients, the follow-up periods were short, and they failed to demonstrate superiority of MNS in safety and efficacy.

The objective of the present study was to evaluate the safety and long-term efficacy of MNS as compared with conventional manual ablation techniques in a large number of patients with consistent technique and workflow.

## Methods

### Patients

This study is an ongoing registry of the procedures performed in our clinic. Six hundred and ten consecutive patients underwent ablation from January 2008 to March 2010. All patients scheduled for EP study and ablation were distributed from the waiting list based on availability to the MNS-equipped or the conventional EP laboratory. Accordingly, ablation was performed either using MNS (group MNS, 292 patients, age  $48 \pm 19$  years, 166 males) or using conventional manual ablation (group MAN, 318 patients, age  $52 \pm 16$  year, 197 males). The procedures were performed over the entire study duration by the same senior electrophysiologist group with the assistance of four fellows, trained for manual catheter navigation and for MNS as well. The attending physicians performed MNS and MAN procedures in equal distribution.

### Electrophysiology studies—ablations

Written, informed consent for the ablation procedure was obtained from all patients. Resting 12-lead electrocardiogram (ECG), and laboratory tests, an X-ray thorax image, and a two-dimensional echocardiography were acquired from all patients within 1 month before and within 48 h following the procedure.

Local peri-procedural medication protocols were followed in all patients. In short, AVNRT, CMT, AT, and elective VT patients were instructed to stop taking antiarrhythmic drugs for a period of at least four half-lives prior undergoing the procedure. In cases of AFib, AV junction (AVJ) and emergency VT ablation medication remained unchanged. The procedures were performed during a fasting state, using local or general anaesthesia. Market-approved diagnostic and ablation catheters were used as clinically required at the discretion of the operator. The left heart could be accessed via the retrograde aortic route or transseptal puncture (TSP) based on the operator's preference. Generally, left-sided ventricular arrhythmias were performed via the retrograde approach (MNS 93%, MAN 89%;  $P = \text{ns}$ ), left-sided atrial arrhythmias always via TSP, and left-sided accessory pathways distributed between the two methods (MNS 22% TSP, group MAN 20% TSP;  $P = \text{ns}$ ). The use of three-dimensional mapping system was allowed in both groups if necessary. Intracardiac echocardiography (ICE) was used to guide TSPs in both groups.

Crossover from the magnetic navigation catheter to manual navigation catheter was allowed at the discretion of the investigator, although the crossover counted as an acute failure for the MNS group. Crossover from the MAN to the MNS group was not possible due to logistical reasons (see below).

The endpoints of procedural success were defined as the elimination of accessory pathway conduction for CMT, the elimination of inducibility and no more than single echo beats for AVNRT, complete AV block for AVJ ablation, bi-directional isthmus block for CTI-

dependent AFL, and complete electrical pulmonary vein isolation for AFib. For VT patients; if the VT was inducible, non-inducibility was the endpoint, if only ventricular extrasystoles (VES) were present, then the complete abolishment of VES assessed by 24 h telemetry counted as acute success. The presence of a pacemaker (PM) or an implantable cardioverter defibrillator (ICD) was not considered as contraindication for MNS-guided ablations.

According to an institutional protocol for the treatment of patients with AFib, all paroxysmal AFib patients were ablated using the cryoballoon technique, the persistent AFib patients were ablated using cryoballoon or MNS, and all long-standing persistent (>12 months) AFib patients were ablated using MNS. Persistent and long-standing persistent AFib procedures included additional linear ablation in the left and/or right atrium. Whenever linear ablation was performed, conduction block was mandatory to be proven. Regardless of the type of AFib patients pulmonary vein isolation was mandatory in all patients. This was always controlled by a 'lasso-type' catheter. Also, atypical AFL and AT patients were ablated generally using MNS (50 of 56, 89%).

### Magnetic navigation system-guided ablations

The procedures were performed in group MNS using the Stereotaxis Niobe II (Stereotaxis, Inc., St Louis, MO, USA) implemented in an EP lab equipped with a Siemens Axiom Artis (Siemens, Erlangen, Germany) fluoroscopy system. The following ablation catheters were used: for AVNRT, CMT and AVJ Celsius RMT (4 mm) (Biosense Webster, Diamond Bar, CA, USA), and for AFib NaviStar RMT ThermoCool (Biosense Webster), AFL/AT and VT Navistar RMT DS (8 mm), NaviStar RMT ThermoCool (Biosense Webster), or Trignum Flux Gold-tip (Biotronik GMBH, Berlin, Germany). The use of an 8 mm tip RMT catheter was associated with a char formation in some patients. Therefore, after the thermocool RMT catheter became available the 8 mm tip catheter was no longer used.

When needed, electroanatomical mapping was performed using the CARTO RMT (Biosense Webster) system.

### Manual-guided ablations

The procedures in the MAN group took place in an EP lab equipped with a Siemens Megalix (Siemens) fluoroscopy system. Electroanatomical mapping was performed using CARTO (Biosense Webster) or EnSite (St Jude Medical Inc., St Paul, MN, USA) system. The following ablation catheters were used: for AVNRT, CMT, and AVJ Biosense Webster B–D curve 4 or 8 mm tip (Biosense Webster), for AFib, AFL/AT, and VT Biosense Webster Navistar ThermoCool (Biosense Webster). The Artic Front cryoballoon catheters (Medtronic Inc., Minneapolis, MN, USA) were used for cryo-isolation of the pulmonary veins; Freezor Max (Medtronic Inc.) catheters were used in cases when complete electrical isolation could not be achieved with the balloon.

### Data collection and analysis

The following parameters were analysed both in group MNS and group MAN: acute success rate, fluoroscopy time, procedure time, and complications. Acute success rate was assessed according to the terms mentioned above. Fluoroscopy time and procedure time (latter began with subcutaneous injection application of lidocaine by the physician to the groin and ended when catheters were removed from the patient's body) were recorded in the clinical procedure log and included a 30 min waiting time. Any adverse event recognized by the operator during the procedure, by the attending cardiologist prior to hospital discharge, or by the general physician during follow-up was investigated by a trained electrophysiologist, and was considered as a

**Table 1 Patient demographics**

	Group MNS	Group MAN	Total
Number	292	318	610
Age (years)	48 ± 19	52 ± 16	50 ± 18
Gender	166 male (57%)	197 male (62%)	363 male (60%)
AFib	56 (19%)	76 (24%)	132 (22%)
Paroxysmal	–	60 (19%)	60 (9.8%)
Persistent	23 (7.9%)	16 (5.0%)	39 (6.4%)
Long-standing persistent	33 (11%)	–	33 (5.4%)
AFL	40 (14%)	84 (26%)	124 (20%)
aAFL/AT	50 (17%)	6 (1.9%)	56 (9.2%)
AVNRT	29 (10%)	70 (22%)	99 (16%)
CMT	55 (19%)	45 (14%)	100 (16%)
AVJ	8 (2.7%)	8 (2.5%)	16 (2.6%)
VT	54 (18%)	29 (9.1%)	83 (14%)
VT-SHD	17 (5.8%)	15 (4.7%)	32 (5.2%)
VT-NSHD	37 (12%)	14 (4.4%)	51 (8.4%)

MNS, magnetic navigation system; MAN, manual navigation; AFib, atrial fibrillation; AFL, cavotricuspid isthmus-dependent atrial flutter; aAFL, atypical atrial flutter; AT, atrial tachycardia; AVNRT, atrioventricular nodal re-entrant tachycardia; CMT, circus movement tachycardia; AVJ, atrioventricular junction; VT, ventricular tachycardia; SHD, structural heart disease; NSHD, non-structural heart disease.

complication if the event could be related to the procedure. Complications were categorized as major and minor [major: pericardial effusion or/and tamponade, permanent AV block, stroke, major bleeding (requiring blood transfusion or haemoglobin serum level drop of >20 g/L) or death; minor: minor bleeding, transient ischaemic attack, and temporary AV block].

Subgroup analysis of the above-mentioned parameters was performed for the following groups: AFib, AFL, atypical AFL (aAFL)/AT, AVNRT, CMT, AVJ, and VT. The AFib group was further divided into the following subgroups: paroxysmal, persistent, and long-standing persistent. Because different techniques were used for the treatment of paroxysmal and long-standing persistent AFib patients, paroxysmal and long-standing persistent AFib subgroups were not compared in efficacy; however, data from these groups were included into the safety comparison (Tables 1 and 2). Patients included into the persistent AFib group were comparable (Tables 1 and 2). The VT group was further analysed in subgroups of patients with and without structural heart disease (SHD and NSHD).

## Follow-up

Follow-up visits were scheduled for all patients at the outpatient clinic of the Department of Cardiology, Erasmus MC 3 months following the procedure, and every 3 months thereafter, except for CMT, AFL, and AVNRT patients, when other than the first follow-up visit was scheduled only if the symptoms recurred. Atrial fibrillation patients were more rigorously followed at the AFib clinic of the department, including daily transtelephonic rhythm strips.

## Statistics

Parameters obtained from the registry were analysed using SPSS 15.0 (SPSS Inc., Chicago, IL, USA). Patient demographic and baseline characteristics were presented as mean ± SD. The two-tailed Student's *t*-test was used for comparing continuous unpaired samples, assuming unequal variances (age, fluoroscopy time, procedure time, and follow-up period). For categorical variables the  $\chi^2$  test was performed (number of patients with different arrhythmias, gender, success rate, recurrence rate, and number of complications). Two-sided *P* values <0.05 were considered significant.

## Results

### Patients

There were no differences in the gender and age between group MNS and MAN (Table 1). There were no differences in the number of patients enrolled into the subgroups based on the diagnosed arrhythmias, except for the subgroups mentioned in the Methods section—paroxysmal and long-standing persistent AFib and AFL/AT (Table 1). There was no difference in the presence of PMs or ICDs between the study groups (PM: 4 MNS vs. 6 MAN, *P* = NS; ICD 20 MNS vs. 21 MAN, *P* = NS). In, two patients (both in the VT group, both had abdominal implant) the ICD switched to magnet mode (asynchronous pacing). None of these patients were PM dependent; therefore, temporary programming allowed electro-anatomical mapping without further problems. No long-term effect on ICD or PM function was observed.

### Ablation

Magnetic navigation system was equally effective as MAN in acute success rate for the overall groups (Table 2). In the subgroups only VT results were different, where MNS was more successful (Table 2). The success rate in the NSHD-VT subgroup was higher in MNS group, whereas the difference in VT subgroup with SHD did not reach statistical significance (Table 2). For the other subgroups no differences were observed in success rates (Table 2).

Crossovers occurred only before the availability of irrigated tip MNS catheters, whereas one CMT patient and two AFL patients underwent crossover from MNS catheters (4 mm for CMT, 8 mm for AFL) to manual guided irrigation tip catheters. Following the crossover all the three patients were ablated successfully. However, the MNS still proved to be non-inferior for the ablation of AFL and CMT. Overall, less fluoroscopy was used in group MNS (Table 3). In the AVNRT and VT subgroups, less fluoroscopy was used in group MNS, otherwise there were no differences between the two groups (Table 3). There were no differences in procedure times between group MNS and MAN. Concerning subgroups, procedure times were higher using MNS in AFL, but were shorter in the VT subgroup.

### Complications

The use of MNS was associated with a lower complication rate (4.5 vs. 10%; *P* = 0.005). Moreover, concerning major complications the difference was also significant between the two groups (0.34 vs. 3.2%; *P* = 0.01). One permanent AV block occurred in the

**Table 2** Ablation results—acute success

	Group MNS	Group MAN	Total	P value
All arrhythmias	269/292 (92%)	298/318 (94%)	567/610 (93%)	0.904
AFib	52/56 (93%)	75/76 (99%)	127/132 (96%)	0.083
Paroxysmal	–	59/60 (98%)	59/60 (98%)	na
Persistent	22/23 (96%)	16/16 (100%)	38/39 (97%)	0.398
Long-standing persistent	30/33 (91%)	–	30/33 (91%)	na
AFL	38/40 (95%)	82/84 (98%)	120/124 (97%)	0.440
aAFL/AT	42/50 (84%)	4/6 (67%)	46/56 (82%)	0.295
AVNRT	29/29 (100%)	68/70 (97%)	97/99 (98%)	0.358
CMT	52/55 (95%)	39/45 (87%)	91/100 (91%)	0.075
AVJ	8/8 (100%)	8/8 (100%)	16/16 (100%)	–
VT	50/54 (93%)	21/29 (72%)	71/83 (86%)	0.013
VT-SHD	14/17 (82%)	10/15 (67%)	24/32 (75%)	0.306
VT-NSHD	36/37 (97%)	11/14 (79%)	47/51 (92%)	0.026

MNS, magnetic navigation system; MAN, manual navigation; AFib, atrial fibrillation; AFL, cavotricuspid isthmus-dependent atrial flutter; aAFL, atypical atrial flutter; AT, atrial tachycardia; AVNRT, atrioventricular nodal re-entrant tachycardia; CMT, circus movement tachycardia; AVJ, atrioventricular junction; VT, ventricular tachycardia; SHD, structural heart disease; NSHD, non-structural heart disease; na, not applicable.

P values listed were calculated based on a two-sample t-test assuming unequal variances between group MNS and group MAN.

**Table 3** Summary of mean fluoroscopy and procedure times for group MNS and MAN

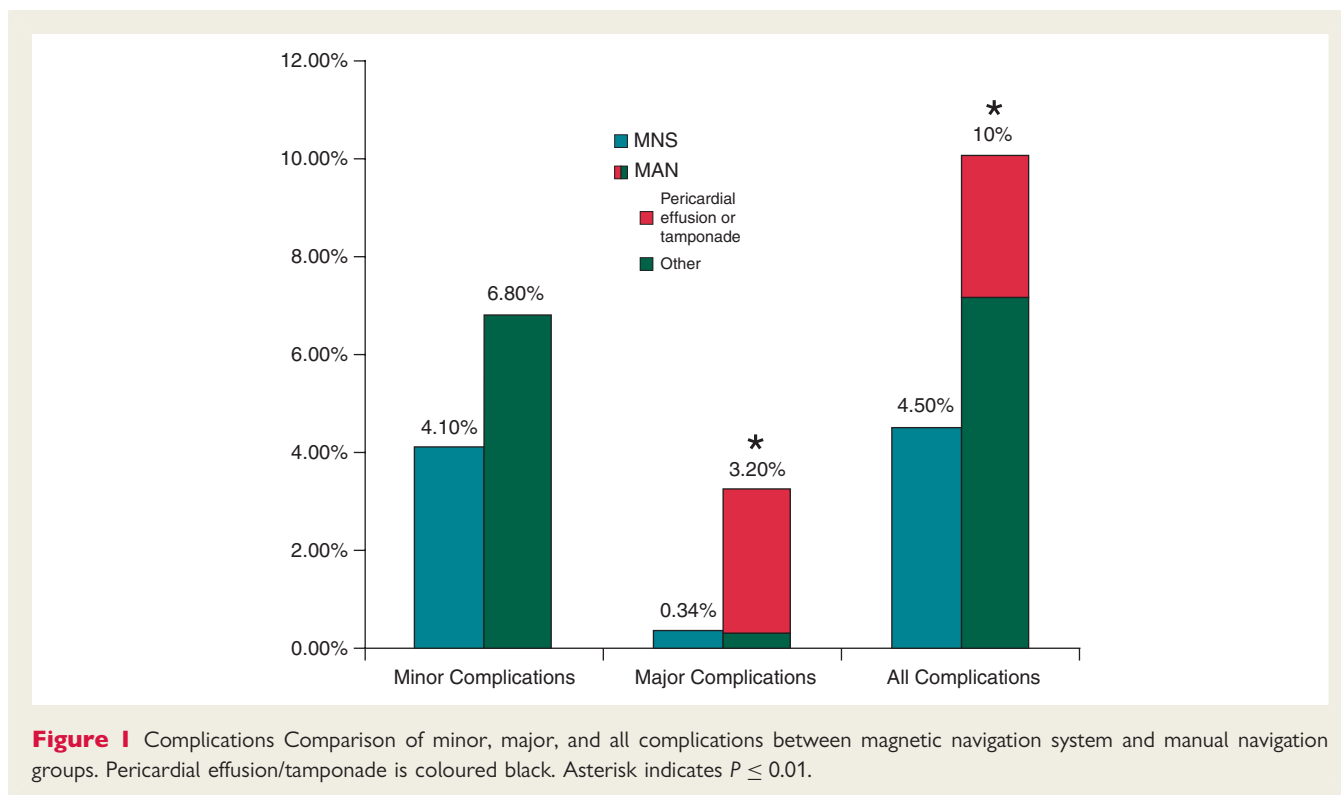
	Fluoroscopy time (min)			Procedure time (min)		
	MNS	MAN	P value	MNS	MAN	P value
All arrhythmias	30 ± 20	35 ± 25	0.009	168 ± 67	159 ± 75	0.119
AFib	44 ± 17	40 ± 22	0.278	248 ± 59	191 ± 81	0.001
Paroxysmal	–	36 ± 19	na	–	168 ± 52	na
Persistent	42 ± 15	54 ± 28	0.061	232 ± 41	276 ± 107	0.088
Long-standing persistent	46 ± 19	–	na	264 ± 70	–	na
AFL	27 ± 13	32 ± 24	0.198	152 ± 44	123 ± 47	0.005
aAFL/AT	37 ± 23	47 ± 20	0.361	188 ± 51	208 ± 53	0.464
AVNRT	12 ± 8.8	25 ± 20	0.001	114 ± 39	136 ± 55	0.068
CMT	28 ± 18	32 ± 27	0.428	134 ± 50	146 ± 57	0.314
AVJ	6.5 ± 2.4	7.7 ± 3.7	0.472	72 ± 7.5	86 ± 21	0.147
VT	27 ± 21	56 ± 31	0.001	166 ± 54	222 ± 97	0.009

MNS, magnetic navigation system; MAN, manual navigation; min, minutes; AFib, atrial fibrillation; AFL, cavotricuspid isthmus-dependent atrial flutter; aAFL, atypical atrial flutter; AT, atrial tachycardia; AVNRT, atrioventricular nodal re-entrant tachycardia; CMT, circus movement tachycardia; AVJ, atrioventricular junction; VT, ventricular tachycardia; na, not applicable. P values listed were calculated based on a two-sample t-test assuming unequal variances between group MNS and group MAN.

MNS and one in the MAN group. The other nine major complications in the MAN group were either pericardial effusion or pericardial tamponade, whereas no effusion/tamponade occurred in the MNS group. There was a trend towards lower minor complications in the MNS group as well, but it did not reach statistical significance (4.1 vs. 6.4%;  $P = ns$ ) (Figure 1). Two temporary AV block were observed in the MNS group, one in the MAN group, the rest of the minor complications were femoral bleeding/haematoma in both groups.

## Follow-up

There were no differences in follow-up periods between group MNS and MAN ( $15 \pm 9.5$  vs.  $14 \pm 9.5$  months,  $P = ns$ ). There were no differences in recurrence rates between group MNS and MAN in overall (14 vs. 11%,  $P = ns$ ) or in any of the subgroups [(AFib persistent 14 vs. 19%) (AFib paroxysmal — vs. 16%) (AFib long-standing persistent 33 vs. 0%) (aAFL/AT 14 vs. 25%) (AFL 13 vs. 11%) (AVNRT 6.9 vs. 7.4%) (CMT 7.7 vs. 5.2%) (AVJ 0 vs. 0%) (VT 14 vs. 14%),  $P = ns$ ].



## Discussion

This is the first study that assesses the efficacy and safety of ablations using MNS vs. manual navigation involving statistically equivalent, large-scaled patient groups. Our series includes all types of arrhythmias, arising from all four heart chambers. There are three major findings of this study. First, MNS proved to be equal to manual ablation not only in acute success rate, but for a reasonable follow-up period in a broader aspect of arrhythmias. Second, MNS was superior in safety as compared with manual navigation resulting in lower number of complications as well as less fluoroscopy times. Third, MNS was found to be better for the ablation of VT.

### Rationale of using MNS for ablations

The success of catheter ablation procedures depends on accurate substrate location, followed by optimal delivery of energy provided by good tissue contact.<sup>24</sup> Manual navigation of catheters in the human heart has limitations: some regions are difficult to reach, and compromised catheter positioning may result in insufficient lesion formation.<sup>13,24</sup> Catheter movement in some positions is accompanied by the risk of major complications, including pericardial effusion or tamponade.<sup>7,24</sup> Although several pre-defined catheter curves were introduced to help appropriate lesion delivery, there are no optimal curves available for the treatment of paediatric patients with small hearts, patients with complex congenital heart defects, or some type of VTs.<sup>25</sup> The introduction and utilization of MNS was aimed at surmounting these difficulties. It provides improvement of safety by the flexible catheter design, and no pericardial effusion or tamponade was reported related to

catheter navigation using MNS.<sup>20</sup> Magnetic navigation system also provides better navigation capability, which is not limited by pre-formed or evolved catheter curves.<sup>19,25,26</sup> Theoretically, non-fluoroscopic imaging and recently built-in automated functions (AutoMap, stored magnetic vectors) allow less fluoroscopy time (to both operator and patient).<sup>18</sup> Stored magnetic vectors also make it possible to re-navigate to spots defined and stored during the procedure.<sup>26</sup> Promising initial results were published concerning these above-mentioned issues.<sup>22,23,25,27</sup> In our experience, automated map function was used in all AFib, aAFI/AT and VT patients undergoing MNS ablation. Manual correction was performed after automated mapping, which could be completed in 5–6 min on average.

### Acute success rates and recurrences

Based on the theoretical advantages mentioned above, MNS could be superior to manual navigation in the analysed parameters. Reports until now focused more on feasibility rather than assessment of efficacy of MNS.<sup>10,11,15,17,23,25–30</sup> Contrary to this, we aimed at comparing large groups of patients treated using MNS or MAN, with a long follow-up period. We confirm that MNS is feasible for ablation of different kinds of arrhythmias, and clearly demonstrate that it provides better safety and uses less fluoroscopy than manual navigation (see below). Furthermore, superiority in acute success rate can be achieved in the VT subgroup (see below).

Certainly, some issues are still to be solved that may play a role in limiting of MNS. The delivered contact force is unknown relative to manual catheters in which it had been shown to affect adequate lesion formation. However, based on the high acute success and

low recurrence rates found in all subgroups during the reasonably long follow-up period, it does not seem to effect patient outcomes. Preparation of the system consumes considerable time (isocentering, registration, merging with CARTO, checking magnet movement). However, it does not result in significant prolongation of the procedures in overall. Although improvements were made recently, we also lack of fully automated functions (no need or automated isocentering; reliable, well-defined automapping) yet.

## Crossovers

In our series, we encountered only three patients, where crossover to manual navigation became necessary (one CMT and two AFI patients). Although the endpoint could be reached using manual navigation in all three cases, no difference was found in general between MNS and MAN concerning the acute success rates in these subgroups. Also, it is important to notice that these crossovers happened before the availability of irrigation tip catheters for MNS.

## Safety of ablations

The use of atraumatic, flexible designed ablation catheters combined with magnetic field-guided navigation resulted in significantly reduced number of complications. No pericardial effusion or tamponade was observed in the MNS group, whereas in the MAN group these proved to be the most frequent major complications. All TSPs were guided by ICE, and none of these complications were related to them. This finding is consistent with previous reports, but these reports failed to substantiate it with significant statistical difference. Two atrioventricular blocks (AVB) occurred in the MNS group (one in a patient with parahisian AT; the risk was discussed with the patient after the diagnosis of the tachycardia was established. The other AVB occurred in a patient with AVNRT during an application near the ostium of the coronary sinus. In this case, our hypothesis is either an ectopic fast pathway or the occlusion of the AVN artery).

Concerning minor complications—dominantly minor bleeding related to the femoral punctures, we also found somewhat higher number in the MAN group, which could be explained by the greater diameter of sheaths used for manual ablation such as cryoballoon sheaths and decreased movement of the sheath at the puncture site during remote catheter manipulation.

The high manoeuvrability and atraumatic design of the MNS-guided ablation catheter allows navigation without constant fluoroscopy control, while re-imaging is typically required after each repositioning of the manual-guided catheter.<sup>18</sup> Furthermore, stored MNS vectors also help to navigate the catheter without repeated fluoroscopic pulses.

As we mentioned in the Methods section, our clinic is an academic centre, and the fellows are taking part of the procedures, including femoral vein and artery punctures, and diagnostic catheter positioning. This significantly influences fluoroscopy or procedure times, and minor complication rates in both groups. Although our data may seem too high at first glance concerning these parameters, they are not really deviated from recently published available data.<sup>31</sup>

## Transseptal puncture or retrograde aortic approach

In our centre, standard approach for left-sided VT is retrograde aortic ablation. Also, in case of left-sided accessory pathway the retrograde aortic approach is preferred. In our experience, this method helps to avoid the chance for serious complications (pericardial effusion/tamponade) and/or the need for expensive diagnostic tools (ICE).

## Ablation of ventricular tachycardia

This is the first large-scale study to prove the superiority of MNS for ablation of VT compared with manual navigation. This is demonstrated in most of the analysed parameters, such as acute success rate, and procedure and fluoroscopy times. There are multiple reasons to explain this finding. The MNS-guided catheter retains its manoeuvrability even in difficult positions, e.g. in cusp-related VTs, papillary muscle-originated VTs, where the capabilities of manual navigation are seriously limited by the multiple curves of the catheter.<sup>11</sup> The MNS controls the tip of the catheter, which means that the unavoidable curves of the catheter do not hinder the positioning of the tip, and good contact can be achieved, resulting in appropriate lesion formation.<sup>13</sup> An MNS-guided catheter has no pre-defined curve, which also contributes to the high manoeuvrability. Moreover, catheter stability using MNS is improved due to the constant magnetic force directing the tip unchanged during application.<sup>13</sup> The above-mentioned capabilities are especially beneficial for patients in whom the arrhythmia substrate is located in a difficult position (i.e. posteroseptal wall in the right or left ventricular outflow tract) or where stability is the major issue (i.e. papillary muscle VTs). Two patients had papillary muscle-originated VT, and five patients had aortic cusp VT in the MNS group, all the seven patients were ablated successfully.

This can explain the difference in success rates between the VT subgroups, whereas statistical significance could be only proven for the NSHD-VT subgroup.

## Limitations of the study

Although this registry is not a randomized, prospective trial, there was not any difference between the two groups and the assignment of the patients to the groups was independent of the operators. However, because of local protocols for the treatment of AFib patients, there were no paroxysmal patients treated with the MNS, and there were no long-standing persistent AFib patients treated manually. This means that only persistent AFib subgroups were comparable, and these groups were not different indeed.

In conclusion, the MNS is equal in terms of acute and long-term success rates compared with MAN, whereas MNS-guided procedures can be performed with a lower complication rate and using less fluoroscopy. For the ablation of VT, MNS is superior to MAN.

**Conflict of interest:** Tamas Szili-Torok is a consultant of Stereotaxis Inc., St Louis, MO, USA.

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