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Short communication

Safety and cost-effectiveness of same-day complex left atrial ablation

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ABSTRACT

Background: Catheter ablation for complex left-atrial arrhythmia is increasing worldwide with many centres admitting patients overnight. Same-day procedures using conscious sedation carry significant benefits to patients/healthcare providers but data are limited. We evaluated the safety and cost-effectiveness of same-day complex left-atrial arrhythmia ablation.

Method: Multi-centre retrospective cohort study of all consecutive complex elective left-atrial ablation procedures performed between January 2011 and December 2019. Data were collected on planned same-day discharge versus overnight stay, baseline parameters, procedure details/success, ablation technology, post-operative complications, unplanned overnight admissions/outcomes at 4-months and mortality up to April 2020. A cost analysis of potential savings was also performed.

Results: A total of 967 consecutive patients underwent complex left-ablation using radiofrequency (point-by-point ablation aided by 3D-mapping or PVAC catheter ablation with fluoroscopic screening) or cryoballoon-ablation (mean age: 60.9 ± 11.6 years, range 23-83 yrs., 572 [59%] females). The majority of patients had isolation of pulmonary veins alone ($n = 846$, 87%) and most using conscious-sedation alone ($n = 921$, 95%). Of the total cohort, 414 (43%) had planned same-day procedure with 35 (8%) admitted overnight due to major ($n = 5$) or minor ($n = 30$) complications. Overall acute procedural success-rate was 96% ($n = 932$). Complications in planned overnight-stay/same-day cohorts were low. At 4-month follow-up there were 62 (6.4%) readmissions (femoral haematomas, palpitation, other reasons); there were 3 deaths at mean follow-up of 42.0 ± 27.6 months, none related to the procedure. Overnight stay costs £350; the same-day ablation policy over this period would have saved £310,450.

Conclusions: Same-day complex left-atrial catheter ablation using conscious sedation is safe and cost-effective with significant benefits for patients and healthcare providers. This is especially important in the current financial climate and Covid-19 pandemic.

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1. Introduction

Complex left-atrial catheter ablation is frequently performed for atrial fibrillation (AF) and atypical atrial flutter/atrial tachycardia. These procedures involve trans-septal puncture and patients are routinely kept overnight to observe for possible complications [1]. Overnight-stay has higher costs compared with same-day procedures. Studies evaluating same-day catheter ablation for AF [2,3] and catheter ablation more widely [4] have suggested same-day ablation is safe, effective [5] and has significant cost-savings for healthcare providers [6–8]. Same-day ablations may benefit patients/healthcare providers by reducing logistic constraints on hospital resources, especially in the current financial climate and Covid-19 pandemic, the latter making overnight hospital-stay challenging. We previously reported same-day standard catheter ablation was safe and cost-effective [6] but data on complex left-atrial ablation are limited. We started performing same-day complex left-atrial ablations in 2016 and wanted to evaluate the safety and efficacy of this policy. We also performed a cost-analysis of potential savings possible by adopting this same-day ablation policy.

2. Methods

This was multi-centre retrospective cohort study of all consecutive elective complex left-atrial ablations performed at University Hospital Coventry, Rugby St-Cross Hospital and Worcester Royal Hospital, UK between January 2011 and December 2019. Data were collected on

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baseline demographics, procedure details, ablation technology (Pulmonary Vein Ablation Catheter [PVAC], 28 mm Arctic-Front Advance Cryoballoon with Achieve mapping catheter [both Medtronic Inc., USA], Carto 3 with Lasso mapping catheter or PentaRay mapping catheter [Biosense Webster Inc., USA], Velocity/Precision with Optima or HD-Grid mapping catheter [Abbott Medical, USA]), ablation success, post-operative complications, outcome at 4-months and mortality. Study approval was obtained from our Research and Audit Department. All procedures were performed by an Electrophysiologist using local anaesthesia (LA) [1% lidocaine] and conscious sedation (midazolam, 0.1 mg/kg intravenously/maximum15mg) with fentanyl pain relief (25μg boluses/maximum200mcg); very few were under general anaesthesia (GA).

Our protocol for same-day complex left atrial ablation started in January 2016 for cryoballoon ablations and June 2017 for 3D-radiofrequency (RF) point-by-point ablations with contact-force sensing. We included all consecutive patients requiring left-atrial ablation (needing trans-septal puncture from outset) chronologically from these dates. Where possible those living further away from the hospital were listed earlier than those living closer to allow timely discharge. Age and geography were not specifically used to exclude patients; exceptions to same-day discharge were allowed on the day at the operator's discretion. Those on vitamin K antagonists (mostly warfarin) had to have therapeutic INRs for at least 1 month pre-op and an INR on the day of between 2 and 3.5. Patients taking a direct oral anticoagulant (DOAC) included those on Dabigatran/Rivaroxaban/Apixaban/Edoxaban; those on once-daily DOACs took their last dose ~20 h pre-procedure, those on twice-daily DOACs took their last dose ~10 h pre-procedure. No trans-oesophageal echocardiography (TOE) was performed in any patient unless the INR was sub-therapeutic on the day or within 3 weeks pre-op. All patients had baseline blood tests and group/save samples taken in pre-op clinic as per our hospital protocol. On admission to Cardiology Day Unit (CDU) patients had their consent confirmed and a point-of-care international normalized ratio (if on warfarin) and peripheral venous access sited. Our procedure protocol details and after-care are shown in Supplement 1.

Patients were anticoagulated pre-procedure with arrhythmia mechanism and ablation strategy formulation in accordance with published guidelines [9]. Unilateral femoral-venous access was performed for PVAC/cryoballoon and bilateral for 3D-RF cases. Duration of 3D-RF application was determined by Force-Time-Integral [10], Lesion-Size-Index [11] or Ablation-Index [12]. A transthoracic echocardiogram (TTE) was performed in all immediately post-procedure with repeat 2-3 h later; protamine 50 mg was administered post-op and femoral haemostasis achieved using digital manual pressure or a 'figure-of-8' (Z) suture [13] using the same-day protocol.

Details of immediate (≤4 h post-procedure) and short-term (>4 h–24 h) complications were collected in addition to need for overnight-stay and readmissions at 4-months post-ablation, as well as mortality up to April 2020. The cost of monitored overnight-stay was obtained and potential savings of adopting the same-day ablation policy during the study period calculated.

2.1. Statistical analysis

All data were analysed using Statistical Package for Social Sciences (SPSS), version 26.0 (IBM, Chicago, Illinois). Continuous variables were expressed as mean ± standard deviation (SD) and nominal data as number and percentage. We compared categorical variables using Chi-squared test and continuous variables using the independent *t*-test.

3. Results

A total of 967 patients underwent complex left-atrial ablation (mean age: 60.9 ± 11.6 years; 572 [59%] female). The majority were performed using LA and conscious sedation only ($n = 921$, 95%); the commonest

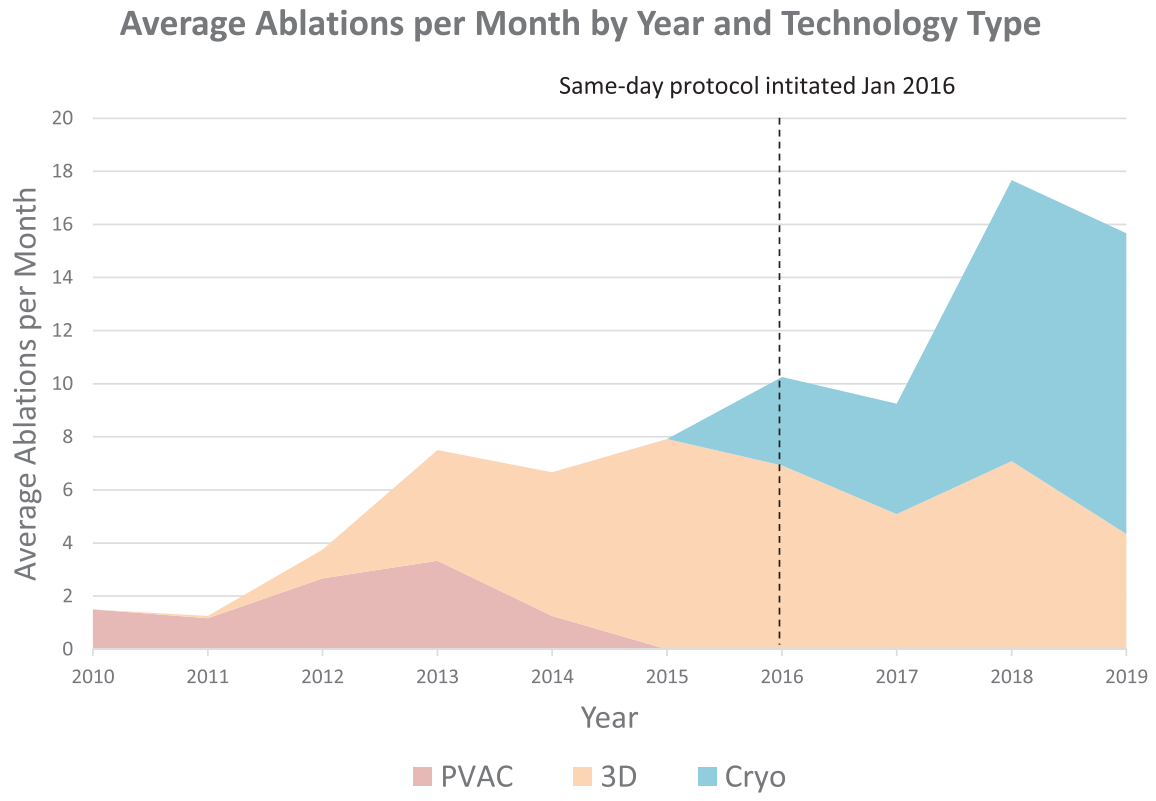


Fig. 1. Evolution of Left Atrial Ablation Technology used over the study period.

Table 1
a. Comparison of baseline and procedure data between same-day and overnight-stay cohorts.

Demographics	Total $n = 967$	Same Day $n = 414$	Overnight $n = 553$	*P*-value
Age mean ± SD	60.9 ± 11.6	62.5 ± 10.8	59.7 ± 12.1	*<0.001*
Age Range	23–83	26–83	23–83	n/a
Female n (%)	572 (59)	227 (55)	345 (57)	*0.020*
Underlying Heart Disease *n* (%)				
None Identified	726 (75)	297 (72)	429 (78)	*0.020*
Ischaemic Heart Disease	39 (4)	13 (3)	26 (5)	0.225
Hypertensive Heart Disease	42 (4)	34 (8)	9 (2)	*<0.001*
Valvular Heart Disease	15 (2)	10 (2)	5 (1)	0.059
Hypertrophic Cardiomyopathy	12 (1)	6 (1)	6 (1)	0.610
Dilated Cardiomyopathy	26 (3)	15 (4)	11 (2)	0.119
Other Cardiomyopathy	32 (3)	20 (5)	12 (2)	*0.022*
Other Heart Disease	16 (2)	9 (2)	7 (1)	0.271
Mixed Disease	10 (1)	6 (1)	4 (1)	0.268
Unspecified	48 (5)	4 (1)	44 (8)	*<0.001*
Arrhythmia pre procedure				
Paroxysmal AF	620 (64)	267 (65)	353 (64)	0.794
Persistent AF	269 (28)	114 (28)	155 (28)	0.884
Long-standing persistent AF	61 (6)	26 (6)	36 (7)	0.773
Other Atrial Arrhythmia (Left atrial tachycardia/atypical flutter)	16 (2)	7 (2)	9 (2)	0.935
No. of previous ablations *n* (%)				
1	102 (11)	30 (7)	73 (13)	*0.002*
2	10 (1)	1 (0.2)	9 (2)	*0.035*
3	2 (0.2)	1 (0.2)	1 (0.2)	0.835
Type of Ablation Procedure *n* (%)				
A Fibrillation – PVI/SOCA/WACA	846 (88)	388 (94)	459 (83)	<0.001
Left Atrial Tachycardia (*Re*-entrant, Focal, Atypical Flutter)	15 (2)	6 (1)	9 (2)	0.828
Combined AF and Other Procedures* *CTI, any Atrial Tachycardia, AV Node Ablation or any combination with AF ablation	105 (11)	20 (5)	85 (15)	<0.001
Anaesthesia *n* (%)				
Local anaesthesia (LA) only	22 (2)	14 (3)	8 (1)	*0.046*
LA + Conscious Sedation (including Fentanyl/Diazepam/Midazolam)	906 (94)	393 (95)	514 (93)	0.207
General Anaesthetic	38 (4)	7 (2)	31 (6)	0.001
Anticoagulation *n* (%)				
None	3 (0.3)	2 (0.5)	1 (0.2)	0.402
Bridging LMW Heparin	256 (26)	179 (43)	77 (14)	*<0.001*
Uninterrupted Vitamin K antagonist	410 (42)	87 (21)	324 (59)	*<0.001*
Uninterrupted DOAC	297 (31)	146 (35)	151 (27)	*0.007*
Ablation Technology *n* (%)				
PVAC	114	0	114	*<0.001*
RF/3D Mapping	489	88	401	*<0.001*
Cryoballoon	347	313	35	*<0.001*
Cryo +3D	16	13	3	*0.002*
Procedure Duration				
Mean Procedure Time (mins)	159.8 ± 76.4	146.2 ± 80.9	169.2 ± 71.8	*<0.001*
Mean Ablation Energy Time (mins)	19.8 ± 22.6	12.0 ± 15.2	25.7 ± 25.4	*<0.001*
External Cardioversion *n* (%)				
None	578 (60)	254 (61)	324 (59)	0.361
AF/AT External	386 (40)	159 (38)	228 (41)	0.351
AF/AT Device	2 (0.2)	1 (0.2)	1 (0.2)	0.836
Acute Procedure Success *n* (%)				
Complete Success	932 (96)	400 (97)	533 (96)	0.850
Partial Success	28 (3)	13 (3)	15 (3)	0.690
Failed	6 (0.6)	1 (0.2)	5 (0.9)	0.195
b. Immediate/short-term complications, readmissions at 4 month follow-up and mortality.				
Major Immediate (≤4 h)	$n = 16$ (1.7%)	$n = 5$ (1.2%)	$n = 11$ (2.0%)	0.345
Vascular Injury/Bleed requiring Surgical Intervention	2	1	1	
Pericardial Effusion/Tamponade requiring Drain	10	1	9	
Stroke	2	1	1	
Hypotension requiring ITU support (Severe vasovagal)	1	1	0	
Acute Pulmonary Oedema requiring ITU support (T2RF)	1	1	0	
Minor Immediate (≤4 h)	$n = 30$ (3.1%)	$n = 8$ (1.9%)	$n = 22$ (4.0%)	0.069
Access Site Bleed/Haematoma (treated conservatively)	12	3	9	
Pericardial Effusion (no drain)	6	1	5	
Reversible Phrenic Nerve Palsy	9	9	0	
Pericardial Effusion + Access Site Bleed	3	1	2	
Major short-term (>4 h to 24 h)	$n = 3$ (0.3%)	$n = 0$	$n = 3$ (0.5%)	0.265
Vascular Injury/Bleed requiring Surgical Intervention or Transfusion	3	0	3	
Minor short-term (>4 h to 24 h)	$n = 31$ (3.2%)	$n = 22$ (5.3%)	$n = 9$ (1.6%)	*0.001*
Bleeding/Haematoma at access site	20	14	6	
Pericardial Effusion (no intervention)	9	7	2	
Access Site Bleed + Effusion	1	0	1	
Reversible AV node injury	1	1	0	
Readmissions at 4-months *n* (%)	$n = 62$ (6.4%)	$n = 29$ (7.0%)	$n = 32$ (5.8%)	0.441
Palpitations/Arrhythmia	18	6	12	
Bleeding from access site	9	3	6	
Pericardial effusion needing drain	1	0	1	
Heart block requiring pacing	2	1	1	
Medication side-effects	1	1	0	
Urinary infection	1	0	1	
Heart failure	1	0	1	
Other reasons unrelated to procedure	29	18	11	
Mortality	$n = 3$ (0.3%)	$n = 1$ (0.2%)	$n = 2$ (0.4%)	0.740
Mean follow-up time (months)	42.0 ± 27.6	20.3 ± 12.7	58.3 ± 24.3	
Number of deaths	3	1	2	
Related to procedure	0	0	0	

arrhythmia was paroxysmal or persistent AF ($n = 846$, 87%). Of the total, 414 (43%) were planned same-day discharge procedures. Complete procedural success was achieved in 932 (96%) with an overall procedure duration of 159 ± 76.4mins. Fig. 1 shows the evolution of different ablation technologies used over the study period. Single-shot technology was used in 461 (48%) (PVAC $n = 114$ and Cryoballoon $n = 347$), RF point-by-point in 489 (51%) and both in 16 (2%). Table 1a shows a comparison of baseline and procedure data between same-day versus overnight-stay cohorts.

There were a total of 46 (4.8%) immediate complications (16major/30minor) and 34 (3.5%) short-term complications (3major/31minor) (Table 1a); all immediate complications occurred within 2 h post-procedure with pericardial tamponade requiring drainage in 10 (1%). Femoral haematomas needing surgical intervention occurred in 5 (0.5%). One patient developed acute pulmonary oedema of unknown cause, requiring invasive ventilation and intra-venous diuretics. Reversible phrenic nerve palsy was noted in 9 (0.9%) cryoballoon cases (all recovered within 24 h) and stroke in 2 (0.2%); none needed cardiac surgery due to procedural complications. During 4-month follow-up there were 62 (6.4%) hospital readmissions for a variety of reasons: 9 femoral bleeds, 1 pericardial-effusion needing drain, and 2 late-presentation heart-blocks needing pacing (Table 1b). Of the 2 pacemakers, one presented 4 weeks post-cryoballoon with intermittent complete heart-block and the second 6 weeks post RF-ablation, both unrelated to the ablation. There were no differences in femoral complications between unilateral versus bilateral venous-punctures (1.7% vs 1.8%, $p = 0.7$ respectively). Overall complications were no different between cryoballoon versus 3D-RF (4.0% vs 5.0%, $p = 0.49$ respectively) or

GA versus conscious-sedation (2.6% vs 4.7%, $p = 0.54$ respectively) cases.

Of those discharged same-day, none developed complications within 24 h that would otherwise have been detected by overnight-stay. There were 86 (20.8%) unplanned overnight admissions, of which 34 were for immediate/short-term complications (as above), 25 admitted at operator discretion and 27 for non-procedure related reasons (late-finish, medication-dispensing delays). There were 3 deaths at mean follow-up of 42.0 ± 27.6 months, none related to ablation.

Overnight-stay, excluding any other procedures, costs ~$500 (£350). Our same-day policy over this period resulted in 327 patients (413 minus 86 unforeseen admissions) discharged same-day resulting in a $163,500 (£114,450) cost-saving. However, if the same-day policy was applied to all during the study period (excluding 79 who had post-procedure complications) $443,500 (£310,450) could have been saved.

4. Discussion

Same-day complex left-atrial catheter ablation, performed using pain relief and conscious sedation, is safe and associated with few complications with a minority requiring overnight-stay or hospital re-admission. Data on same-day complex left-atrial ablations are limited [3,7,8] with many centres admitting patients overnight, which has inherent cost-implications and is associated with significant risk given the Covid-19 pandemic [14]. Performing same-day complex left atrial ablation can help mitigate risk of Covid-19 transmission and reduce cost-burden on healthcare providers worldwide.

We previously reported *standard* same-day ablation was safe/cost-effective [6]; applying the same principles to complex left-atrial ablation could have significant benefits. Opel et al. [8] demonstrated safe and successful same-day AF cryo-ablation. Utilising a same-day strategy for all left-atrial ablations irrespective of ablation technology could significantly reduce logistic constraints on hospitals, especially given the increasing volume of such cases being performed worldwide [9]. This is even more important with the high demand for inpatient beds by services such as Acute Medicine, resulting in elective procedure cancellations and delays. In our study 20% same-day patients had unplanned overnight-stay, with the majority not due to a complication. This was likely related to the initiation phase of the same-day protocol, with operators initially being over-cautious, and logistics constraints caused by late finishes/patients living further away. These considerations can limit implementation of the same-day policy but are not insurmountable with careful planning/experience.

Overall we noted low complications and high acute procedural success. Most immediate and short-term complications were femoral haematomas/bleeding ($n = 37$, 3.8%) and only 5 (0.5%) needed surgical intervention. Interestingly, lack of use of TOE did not appear to confer disadvantage as our stroke/transient ischaemic attack rate was very low although we did not screen for silent-strokes as this is not recommended in guidelines [9]. We reported two stokes in our cohort and therefore recognise that pre-op TOE may have identified intra-cardiac thrombus which would have aborted the procedures. Our cost-analysis suggests significant savings are possible with same-day ablations. Cases cancelled due to overnight-bed unavailability result in worse outcomes and unnecessary delays. The technologies used in our study reflected real world practice with both RF and cryo-ablation included. Previous authors have shown same-day AF-ablation is safe and effective [3,7,8], however, these have had small same-day numbers [7], used single-technology (cryoballoon) [8] or were done only under GA [3]. To date, no recommendations have been made about same-day complex left-atrial ablations in international guidelines [9]. The current study is from an experienced high-volume centre. Our findings would apply to similar high-volume centres and not centres with less patient volumes/operator experience as previous studies have outlined the role that less experience plays in patient safety [9].

4.1. Study limitations

We had no data on morbidity at longer-term follow-up. Additionally, it is possible some may have developed minor complications (e.g. small groin-haematomas) that may have resolved spontaneously before 4-month follow-up and for which the patient may not have sought medical advice. This could result in under reporting of minor complications. Also, certain arrhythmias (such as left-atrial tachycardia) were limited in number. Our study was non-randomised with no control group. Also, our historical overnight-stay comparison group has limitations given the advances in technology/procedural-care that have occurred during the study time-period.

5. Conclusions

Complex same-day left atrial ablation is safe, cost-effective and has significant benefits for patients and healthcare providers. This is particularly important in the current climate when hospitals are facing enormous challenges, both clinical and financial.

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Declaration of Competing Interest

None to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2020.09.066.

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