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Oesophageal Pacing for non-invasive Verification of Left Atrial Posterior wall Isolation - Follow-Up post Atrial Fibrillation Ablation

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Abstract

Background: Left atrial posterior wall isolation (LAPWI) has been proved to be beneficial in long standing persistent atrial fibrillation (AF). This study aims to assess the accuracy of oesophageal pacing catheters to detect reconnection at a time point during long-term follow-up remote from the isolation procedure.

Method: This is a prospective study and includes patients who underwent ablation therapy (catheter or hybrid) for long standing persistent AF, where LAPWI was judged to have been achieved based on surgical or catheter ablation criteria. Patients underwent oesophageal pacing and recording at an interval greater than 6 weeks following initial ablation. Subsequent to this, all patients underwent a left atrial electrophysiology (EP) study to confirm or refute findings from the oesophageal study.

Results: In 20 out of 21 patients studied, the oesophageal catheter study correlated with the invasive EP study. The negative predictive value of this test is 95.00 % (95% CI of 74.29% to 99.92%), where a negative result is being unable to capture the atrial rhythm by oesophageal pacing indicating that the LAPW remains isolated. The positive predictive value is 100%, where a positive finding indicates being able to capture the atrial rhythm by oesophageal pacing indicating that the LAPW has reconnected.

Conclusions: We were able to demonstrate that oesophageal pacing catheters can successfully be used for verification of LAPWI. This is important in assessment of the long-term efficacy of LAPWI and also in informing operators of the durability of the results they are achieving by either catheter or surgical ablation.

Introduction

Pulmonary vein isolation (PVI) is the cornerstone for managing patients with paroxysmal atrial fibrillation (AF)[1]. However, in individuals with non-paroxysmal AF, additional lesion sets in the left atrial posterior wall (LAPW) may be required to prevent recurrences. The LAPW shares a common embryological origin with the pulmonary vein and has electrophysiological characteristics that give rise to its arrhythmogenic potential[2]. LAPW isolation can be achieved through additional lesion sets on top of PVI, such as adding 'roof lines' between right and left superior pulmonary veins (PV) and 'floor lines' between the right and left inferior PVs. These lesion sets are based on the main principle of the modified Cox-Maze surgical technique[3]. Besides catheter ablation, LAPW isolation can also be achieved by thoracoscopic surgical ablation (SA), or a combination hybrid approach. Ablation procedures do come with risks, some of which are serious. These include stroke, fatality and cardiac tamponade[4]. The oesophagus runs a variable course in the posterior aspect of the left atrium (LA)[5]. Given the close anatomical relationship between the two structures, there is a small risk of atrio- oesophageal fistula from ablation procedures, which is often fatal[4]. Safety mechanisms such as specialized oesophageal temperature probes have been developed for use during ablation procedures to reduce the risk of atrio-oesophageal fistula[6]. However, they cannot measure every point within the oesophagus and so can never provide complete safety.

In our initial feasibility study, 7, we were able to establish that an oesophageal pacing catheter can be used to confirm or refute LAPW isolation with a sensitivity of 100% and specificity of 95% during an invasive isolation procedure. In this study, we aim to prospectively assess the positive and negative predictive value of using oesophageal pacing to detect reconnection at a time point during long-term follow-up after the isolation procedure, without the need for any hospital admission. The verification of isolation was then compared to a subsequent gold standard invasive electrophysiological (EP) study.

Key Words

Atrial fibrillation; Posterior-wall isolation; Oesophageal pacing.

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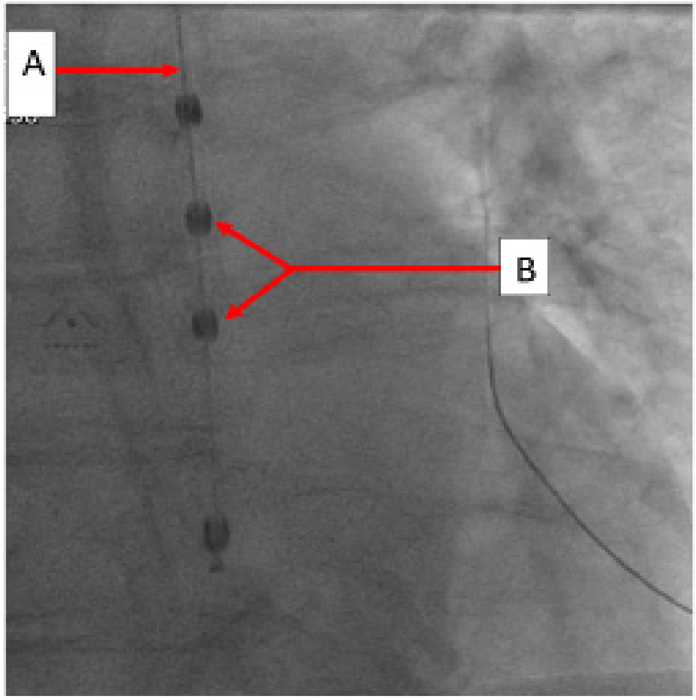

Figure 1: A: Antero-posterior fluoroscopic projection of the oesophageal catheter ('Box Check' Oesophageal catheter, Dot Medical Limited, U.K.), which is positioned posterior to the left atrial wall. B: Oesophageal pacing is performed through the middle poles of the catheter

2. Method

2.1 Study Cohort and recruitment

This a prospective study of patients who were recruited from the electrophysiological service at the South West Cardiothoracic Centre, University Hospitals Plymouth, United Kingdom between 2014 and 2019. The inclusion criteria for this study are patients who underwent ablation therapy (catheter, surgical or hybrid) for symptomatic, drug-refractory persistent AF aiming to achieve LAPW isolation. The decision regarding a catheter or staged hybrid ablation approach was based on the multi-disciplinary team and patient discussions. Patients underwent oesophageal pacing and recording at an interval greater than 3 months (ranging from 5 months to 120 months) following surgical or catheter ablation where LAPW isolation was judged to have been achieved based on surgical or catheter ablation criteria. Subsequently, all patients underwent a further left atrial EP study at which the predicted result from the oesophageal study was either confirmed or refuted.

Ethical approval was granted for all the participants of this study by the Devon and Cornwall Research Ethics Committee prior to the recruitment stage. Informed consent was obtained from all the patients prior to the study. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee.

2.2 Procedures

2.2.1 Oesophageal Pacing and Recording

The quadra-polar oesophageal catheter ('Box Check' Oesophageal catheter, Dot Medical Limited, U.K. – Figure 1) is placed while the patient is laid supine on the fluoroscopy table (with or without mild sedation depending on patient preference). The catheter itself is 75 centimetres long and 2.3 millimetres in diameter with an inter-electrode distance of 10 millimetres. In patients in sinus rhythm, the only preparation required is the attachment of a bedside electrocardiogram monitor. The oesophageal pacing catheter is passed through the left or right nostril depending on patient preference, prior success with naso-gastric tubes, or presence of a deviated septum. On passing the catheter through the nasopharynx, the patients are advised to swallow. The 2 middle pacing electrodes on the 'BoxCheck' catheter are positioned immediately behind the isolated region of the LAPW using fluoroscopy to check for correct positioning (see section 4.1). The pacing was performed in a bipolar fashion and the pulse width was set at 10 milliseconds. The amplitude was initially set at 5mA, and increased up to 20mA (at a rate above sinus) until there was either capture of the atrial rhythm or 20mA was reached without capture. If capture of the atrium was not achieved at 20mA, the study predicted that isolation of the left atrium with bidirectional block across the ablation lines enclosing the left atrial posterior wall would be found at the subsequent invasive EP study.

2.2.2 Endocardial instrumentation at the subsequent invasive EP study

Access to the left atrium was gained via atrial trans-septal puncture using fluoroscopic guidance. Patients were heparinised during the procedure, aiming to achieve an activated clotting time greater than 300 seconds. An SL-1 sheath (Abbott Inc., St. Paul, Minnesota, USA) was passed through the aperture created by the trans-septal puncture and an A Focus 2 mapping catheter was placed on the left atrial posterior wall to sense and pace.

2.2.3 Endocardial electrophysiological mapping and ablation

Patients received direct current cardioversion to achieve sinus rhythm if they were in AF. This permitted pace capture and mapping in sinus rhythm. We used the Abbott Inc. Precision mapping system and the AFOCUS II catheter (Abbott Inc. Medical, St. Paul, Minnesota, USA) to create a three- dimensional voltage map of the left atrium. Our standard settings were between 0.1mV - 0.13 mV (grey colour scale) to 0.5mV (purple colour scale). Healthy tissues were denoted by areas of higher voltage, and scar tissue was marked by areas of low electrical amplitude (e.g., surgical ablation areas). Electrical isolation was checked by placing the AFOCUS II catheter (Abbott Inc. Medical, St. Paul, Minnesota) in the LAPW and PV. An EP study was then performed assessing for entry (absence of sinus beats conducted inside the box lesion) and exit blocks (absence of capture of the atrium by pacing above the sinus rate) at several points within the ablation 'box' of the LAPW (10mA@2ms).

3. Results

3.1 Patient cohort

A total of 21 patients (Table 1) were studied. 4 patients had undergone catheter only ablation, 16 patients had undergone hybrid ablation procedures and 1 patient was studied 120 months post concomitant surgical ablation. Of the patients who had hybrid ablation, 9 patients had undergone both surgical and catheter ablation prior to

Table 1: Summary of findings from Oesophageal pacing study compared with an invasive EP study

Patient details				Ablation Strategy aiming to achieve LAPW isolation	Findings from Oesophageal Pacing study		Findings from invasive EP study subsequent to the oesophageal study		Oesophageal study consistent with restudy EPS?	Complications	Comments
Age	Sex	BMI	LA size (mm)		LAPW Capture @ 20 mA	LAPW isolation status	LAPW isolation status	LAPW established with RF			
76	M	26	47	Catheter	No	Isolated	Isolated	Already established	Yes	No	
76	F	22	42	Catheter	Yes	Not isolated	Not isolated	Yes	Yes	No	
78	M	24	48	Catheter	Yes	Not isolated	Not isolated	Yes	Yes	No	
75	M	26	39	Catheter	Yes	Not isolated	Not isolated	Yes	Yes	No	
52	M	33	39	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
73	M	30	58	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
74	M	22	48	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
72	M	28	41	Hybrid	Yes	Not isolated	Isolated	Already established	no	No	Oesophagus close to right veins - narrow area of isolation at this site. When correctly positioned oesophageal pacing failed to capture at 25mA.
69	M	34	59	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
59	M	31	55	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
57	M	33	40	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
73	M	26	32	Hybrid	Yes	Not isolated	Not isolated	No	Yes	No	PVI procedures x2 prior to Hybrid AF ablation. CTI line only added at 2nd stage catheter ablation
72	M	27	48	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
68	M	32	50	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
59	M	32	47	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
72	M	26	52	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
62	M	26	42	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
68	M	25	50	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
73	M	24	49	Hybrid	Yes	Not isolated	Not isolated	Yes	Yes	No	
68	M	26	40	Hybrid	No	Isolated	Isolated	Already established	Yes	No	
83	M	25	51	Surgical Concomitant	No	Isolated	Isolated	Already established	Yes	No	

the oesophageal pacing study, and 7 patients had just undergone the initial surgical stage at the time of the oesophageal pacing study.

Following invasive left atrial EP studies, 10 patients had achieved LAPW isolation from their index procedure/s and 11 patients had breakthrough lines from their original LAPW isolation procedure requiring further ablation. Out of the 11 patients that needed further ablation, LAPW isolation was subsequently achieved in 10 patients through radiofrequency catheter ablation.

3.2 Oesophageal recording and pacing

In 20 out of 21 patients, findings from the oesophageal catheter study correlated with the invasive EP study. In one patient, we were able to capture at 20mA despite having evidence of LAPW isolation at the subsequent invasive study. On review of this case, we noted that the oesophagus was anatomically positioned close to the right pulmonary veins and this particular zone had a narrow area of isolation between the roof and floor lines. The oesophageal pacing catheter was reintroduced during the invasive study to understand the mismatch in predicted result and actual result of the isolation procedure. When correctly positioned with the central 2 electrodes of the oesophageal pacing catheter behind the narrow-isolated area of the LAPW, oesophageal pacing failed to capture at 20mA (Figure 2).

3.3 Comparison between Oesophageal and Invasive Electrophysiological study

There was one false negative in the study, where it was possible to pace the LAPW despite LAPW isolation. With this in mind, the results from this study gives a negative predictive value of 90.00 % (95% CI of 57.95% to 98.33%). A true negative result is defined as the inability to pace the left atrium in patients with LAPW isolation. The positive predictive value is 100%, where a true positive finding indicates the ability to pace the left atrium in the absence of LAPW isolation. The sensitivity is 91.67% (95% C.I. 61.52% to 99.79%) and specificity is 100% (95% CI of 66.37% to 100%). This analysis has been illustrated in table 2.

Table 2: Sensitivity and specificity analysis of oesophageal pacing catheters in being able to predict LAPWI

True Negative (LA non-capture in the setting of LAPWI)	9
False negative	1
True Positive (LA capture in the setting of electrical reconnection)	11
False positive	0
Sensitivity	91.67%
Specificity	100%

Key
LA – Left Atrium, LAPWI - Left Atrial Posterior Wall isolation

3.4 Complications

No complications were observed in our current patient cohort. No patients complained of residual effects of the oesophageal study.

4. Discussion

The posterior wall of the left atrium is located between the left and right pulmonary veins. In essence, it should be thought of as an extension of PV from an anatomical, embryological and electrophysiological standpoint[8]. Persistent pulmonary vein isolation remains difficult to achieve. Reconnection rates have sometimes been reported to be as high as >70%[9]. This is more so the case in patients with longstanding persistent AF with larger atria, and therefore additional ablative lesions are advocated in such patients[10]. STAR AF 2 trial showed no advantage in the use of additional lesion sets in conjunction to PVI. However, the lesion sets used to achieve left atrial posterior wall isolation were not tested in STAR AF2[11].

Studies to date have provided evidence that LAPW isolation gives additional value to PVI in certain groups of patients with atrial fibrillation [12 - 19]. Kim et al., in their randomized trial of 120 patients with long-standing persistent AF, have shown that AF recurrence rate in one year was significantly lower in those with LAPW isolation compared to PVI alone (16.7% vs. 36.7%)[14]. Other noteworthy randomized studies looking at patients with long standing persistent AF include CASA-AF[15] and CONVERGE[16] trials. The CONVERGE trial compared LAPW isolation to PVI with or without a roof line and also showed that LAPW isolation was more effective than PVI in preventing AF recurrences and reducing symptom burden from AF. However, interpreting the results from such trials are limited by uncertainty over whether the LAPW remains isolated during long term follow up. Reconnection across the wide area circumferential ablation (WACA) lines performed with radiofrequency ablation remains at a minimum of approximately 20% of cases even in the hands of experienced operators using contact-force sensing catheters and guided by Ablation-index (PRAISE Study)[17]. It is likely that reconnection across the roof or floor line occurs at least as common, and if so the clinical benefit from adding LAPW isolation to PVI may have been underestimated.

There are several means to pace the heart temporarily. Transcutaneous pacing offers a quick and non-invasive means to treat severe-symptomatic or haemodynamically unstable bradyarrhythmias. This is achieved by delivering pulses of electricity to the precordium usually through self-adhesive pads. The main disadvantage of transcutaneous pacing is that it can cause painful stimulation of the cutaneous nerves and skeletal muscles[20]. Transvenous pacing offers a durable solution to those who need temporary pacing for longer periods of time. Following venous access (usually via subclavian vein, internal jugular vein or femoral vein), a pacing electrode catheter is placed in the right ventricle with the goal of restoring effective cardiac depolarization. This method however, carries a low probability of developing serious complications such as vascular injuries, septal / right-ventricular free wall perforation, and eventually cardiac tamponade[21].

Transoesophageal pacing is another form of temporary pacing and has the potential to replace invasive pacing in many circumstances[22, 23]. It can be a very useful in measuring electrophysiological properties in a non-invasive fashion. Historically, oesophageal pacing was also used for sinus node evaluation, atrio ventricular node conduction delay, and assessment of paroxysmal supra ventricular tachycardia[24]. However, this has been largely replaced by invasive electrophysiological studies. In a pediatric setting, it can be used for emergency pacing[25,26]; but in adults, this is superseded by intravenous temporary pacing wires. More recently, oesophageal catheters have been implicated in ambulatory monitoring due to the superior monitoring of atrial activity in comparison to a 12-lead electrocardiogram[27]. The theoretical adverse effects of oesophageal pacing include dyspepsia, discomfort/ nausea during insertion, and soft tissue injury. There have been no reports of serious / long-term complications in this pacing modality.

In our latest study, we were able to show the effectiveness of oesophageal pacing catheters in confirming or refuting the preservation of LAPW isolation during long term follow-up using a very simple protocol. Findings from the oesophageal study correlated with invasive EP study in 20 out of 21 patients. One patient had a false negative result from oesophageal pacing (no exit block despite LAPW isolation). The sensitivity and specificity for the oesophageal pacing and recording procedure in assessing reconnection from LAPW isolation in the long term is 92% and 100% respectively. These results are promising; however, a larger multicentre study is still required to prove the general applicability of the technique. While an invasive EP procedure remains 'gold standard' in determining LAPW isolation, there are inevitable risks associated with this procedure, such as stroke and cardiac tamponade. Oesophageal pacing and recording offers a safe and quick way of identifying LAPW isolation without the need for general anaesthesia.

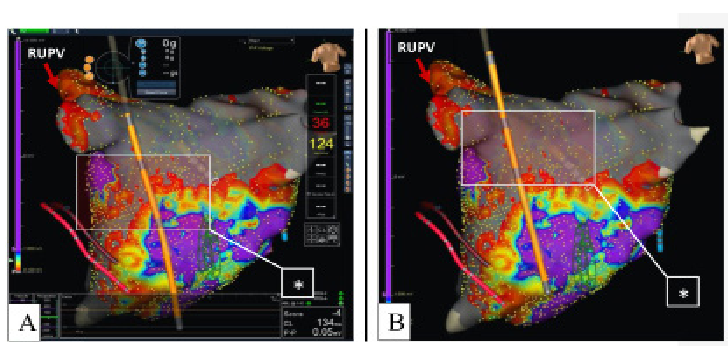

Figure 2: A: Precision map (Abbott Inc., St. Paul, Minnesota, USA) of the left atrial chamber with the 2 middle pacing electrodes (Asterix) of the oesophageal catheter advanced too far, resulting in capture of the atrium with pacing at 20mA. B: Oesophageal pacing is performed through the middle electrodes of the catheter with the catheter positioned correctly with no capture at 20mA.

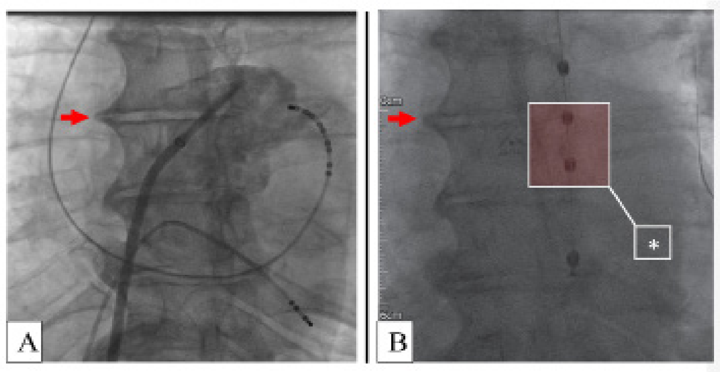

Figure 3: A: Antero-posterior (AP) projection illustrating the roof of the left atrium in line with the sharp osteophyte on the mid thoracic intervertebral disc (Arrow) in the index ablation procedure. B – Roof level osteophyte marker used for correct positioning of middle 2 electrodes (Asterix) on oesophageal pacing catheter to verify electrical isolation during long term follow-up

It could be argued that operators performing LAPW isolation should assess the long-term efficacy of the procedures they perform using such a technique. This could then feedback beneficially in achieving optimal outcomes from their work and demonstrate that an appropriate percentage of durable LAPW isolation is being achieved by the operator compared to their peers. This would apply both to catheter and intra-operative surgical AF ablation. It could also be of importance in judging the efficacy of different modalities in achieving durable isolation lines. This could be of especial importance in understanding the results of clinical trials where head-to-head comparisons of such techniques have been made, such as the CASA-AF study[15]. Oesophageal pacing could be of particular use in patients who need follow-up assessment after an apparently successful LAPW isolation ablation procedure due to AF recurrence. Knowing that the previously established LAPW isolation is intact or has reconnected may alter the methodological and mapping approach to any subsequent ablation procedures.

4.1 Tips to improve diagnostic accuracy of oesophageal pacing catheter

The optimal position of the two central electrodes in the oesophageal catheter used for pacing and recording could be documented for future reference during the initial LAPW isolation procedure (if fluoroscopy is used at the time of the initial procedure). The oesophageal catheter can also be positioned in relationship to the inter-vertebral discs and vertebral osteophytes seen fluoroscopically to be in the area isolated at the index LAPWI procedure (Figure 3). In patients who have undergone prior coronary artery bypass grafting and a catheter LAPW isolation procedure, the location of the isolation zone could be documented with reference to sternotomy wires, left atrial appendage occlusion clips or bypass graft clips seen on fluoroscopy at the time of the catheter ablation. Following concomitant or standalone surgical AF ablation, knowledge of the type of ablation device used and the cardiac silhouette may help guide correct placement of the oesophageal catheter. Left atrial appendage clips, if present, are particularly helpful in indicating the level of the area of isolation. It is worth noting if the course of oesophagus is unusually far out of line with the left atrium, as may occur where procedures such as lobectomy have been performed previously, further assessment with oesophageal catheters may not be advocated in such patients. Finally, we feel that the oesophageal pacing study should be contra-indicated in patients with intrinsic oesophageal diseases such as Barrett's oesophagus or strictures, in order to avoid the chances of false positives.

5. Limitations

This is a small, single centre, prospective trial. Larger multicentre studies are needed to confirm the positive and negative predictive values of oesophageal catheter studies in multiple operators' hands. This technique was found to be inaccurate in one patient where the oesophageal position coincided with a particularly narrow distance between the roof and floor lines. In our previous study[7], one patient had Barrett's oesophagus which also impeded the diagnostic ability of the oesophageal pacing catheter, possibly as a result of oesophageal scarring.

In catheter ablation, LAPW isolation can be achieved by a single circle[28] enclosing the four pulmonary veins and the LAPW, or by wide area circumferential ablation (WACA) of the pulmonary veins, following which the roof and floor lines are added[14]. The oesophageal catheter is accurate in identifying electrical isolation in areas between the roof line, floor line, and the posterior aspect of the WACA. However, this technique is not able to identify reconnection across the anterior aspects of the PVI WACA lines. The oesophageal pacing technique is not suitable for assessing reconnection at the cavo tricuspid isthmus and mitral isthmus lines.

6. Conclusion

We have demonstrated in a prospective fashion that, in patients who have previously undergone a LAPW isolation procedure, oesophageal pacing catheters can successfully identify reconnection across LAPW ablation lines or, conversely, confirm preserved LAPW isolation. This technique can negate the need for an invasive EP study, which is more expensive, requires hospital admission, and is less safe.

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