ORIGINAL ARTICLE

Coarse fibrillatory waves in atrial fibrillation predict success of electrical cardioversion

Tian X. Zhao MA, MPhil, MBBChir, MRCP^{1,2} | Claire A. Martin MA, MBBChir, MRCP, PhD^{1,3} | John P. Cooper MBBS, FRCP, MD¹ | Parag R. Gajendragadkar MA, MPhil, MBBChir, MRCP^{1,4}

¹Department of Cardiology, Bedford Hospital, Bedford, UK

²Division of Cardiovascular Medicine, Department of Medicine, University of Cambridge, Cambridge, UK

³Department of Cardiology, Papworth Hospital NHS Foundation Trust, Cambridge, UK

⁴Division of Cardiovascular Medicine, Radcliffe Department of Medicine, University of Oxford, Oxford, UK

Correspondence

Parag R. Gajendragadkar, MRCP, Division of Cardiovascular Medicine, Radcliffe Department of Medicine, John Radcliffe Hospital, Oxford, UK.
Email: pgajendragadkar@nhs.net

Background: To determine whether the presence of “coarse” fibrillatory waves (Fw) seen on surface ECGs of patients with persistent atrial fibrillation (AF) predict maintenance of sinus rhythm (SR) at 6 weeks after electrical cardioversion (ECV).

Methods: Preprocedure ECGs from 94 consecutive patients with persistent AF scheduled to undergo ECV at a single centre were classified as having coarse Fw (≥ 0.1 mV) or fine Fw (< 0.1 mV) in leads II or V₁. The primary outcome was ECG rhythm at 6-week clinical follow-up. Demographic and echocardiographic data were also collected.

Results: Thirty-two patient ECGs (34%) had coarse Fw on baseline ECG in either or both leads II or V₁ with no significant differences in baseline demographics compared to those patients with fine Fw. At 6 weeks post-ECV, in the coarse Fw group 72% of patients maintained SR vs. 42% in the fine Fw group (χ^2 , $p = .006$) with the odds ratio (OR) of maintaining SR at 6 weeks in the presence of coarse Fw being 3.5 (95% CI: 1.4–8.9, $p = .007$). Across the overall study population, there were no other significant univariate predictors of SR at 6 weeks post-ECV.

Conclusion: Classifying persistent AF using the maximal Fw amplitude on a surface ECG is a simple and reproducible method of predicting medium-term success of ECV, independent of traditional risk factors.

KEYWORDS

atrial fibrillation, electrocardiogram, electrophysiology

1 | INTRODUCTION

Atrial fibrillation (AF) is the most common arrhythmia in the developed world and electrical cardioversion (ECV) is an established part of a rhythm control strategy for the management of AF; in European Society of Cardiology guidelines, ECV is recommended “in symptomatic patients with persistent or long-standing persistent AF as part of rhythm control therapy” (Kirchhof et al., 2016). In the catheter ablation era of AF management, ECV is useful clinically to see if symptoms attributable to AF improve and may be considered in patients who are felt not to be suitable for catheter ablation.

The initial procedural success rate of ECV in restoring sinus rhythm (SR) is high at approximately 70%–90% (Siaplaouras, Jung, Buob, &

Heisel, 2004; Van Gelder, Crijns, Van Gilst, Verwer, & Lie, 1991). This variability is explained in part by differences in patient characteristics and in part by the definition of success. Success can be defined as maintenance of SR immediately after ECV or for several days. However, long-term follow-up shows that only 30%–40% of patients maintain SR at 1 year (Van Gelder et al., 1991). Predicting success of ECV has remained difficult and previous work has investigated traditional “patient” risk factors including increasing age, longer arrhythmia duration, and coronary disease, as well as ejection fraction, left atrial appendage size, P-wave dispersion, entropy of RR interval, and atrial harmonic decay (Grönberg et al., 2015; Holmqvist et al., 2006; Raitt et al., 2006; Van Gelder et al., 1991; Zohar, Kovacic, Brezocnik, & Podbregar, 2005). However, these factors are often not strongly

FIGURE 1 Representative surface electrocardiograms from patients with atrial fibrillation. (a-c) show “coarse” fibrillatory waves with maximum amplitude ≥ 0.1 mV. (d) and (e) show “fine” fibrillatory waves with maximum amplitude < 0.1 mV

predictive or alternatively difficult to measure routinely in a clinical setting without specialist equipment.

Fibrillatory waves (Fw) are found on the surface 12-lead electrocardiograms (ECGs) of patients in AF (Figure 1). They are oscillations in amplitude around the baseline and are dependent on the magnitude of the underlying voltage. This in turn is related to structural factors—i.e. the amount of remaining viable atrial muscle, as well as electrophysiological factors—i.e. the underlying sustaining mechanism of AF and electrical atrial remodelling in that individual. Fw can be reliably categorized by maximal amplitude into either fine (< 0.1 mV) or coarse (≥ 0.1 mV) and this is usually performed in lead II and V_1 (Peter, Morris, & McIntosh, 1966; Thurman & Janney, 1962). They are simple to measure and are reproducible from one ECG to another over 24 hr in clinically stable patients (Xi, Sahakian, Ng, & Swiryn, 2004).

Studies regarding the association of Fw with underlying echocardiographic parameters are inconsistent with some having reported fine Fw to be associated with larger left atrial size, more thrombus in the left atrial appendage (LAA) and lower LAA velocity, whilst others have found no effect or the opposite (Blackshear, Safford, & Pearce, 1996; Mutlu et al., 2003; Yamamoto et al., 2005). Electrical mapping studies have shown a relationship between a coarse AF pattern on surface ECG and intrinsic organized atrial activity during AF (Saksena, Skadsberg, Rao, & Filipecki, 2005; Saksena et al., 1999). Research has subsequently suggested that Fw amplitude is inversely correlated with age and duration of persistent AF and directly correlated with acute success of persistent AF ablation (defined as ablation until AF termination) (Nault et al., 2009) and chronic freedom from AF after persistent AF ablation (Zarzoso et al., 2016).

Therefore, we hypothesized that a maximal amplitude of Fw > 0.1 mV on surface ECG predicts success of ECV by acting as a simple clinical surrogate of underlying electrophysiological and structural properties.

2 | METHODS

We conducted a single centre retrospective observational study by examining patients' medical notes, ECGs and echocardiograms for

138 consecutive ECVs occurring at a single hospital (Bedford Hospital, Bedford, UK) between April to November 2014. Clinical history, demographics, drug treatment, and procedural details were obtained from the medical notes. Echocardiographic data were measured, collected, and analyzed independently and blinded from the ECV result either by a cardiologist or British Society of Echocardiography accredited cardiac physiologist.

2.1 | ECG analysis

Twelve-lead ECGs were performed in a standard manner using a Mortara ELI 250 electrocardiograph machine (Mortara, Milwaukee, WI, USA) using standard ECG lead placement. ECGs were obtained at 25 mm/s and at 10 mm/mV with low and high pass filters of 0.05 Hz and 100 Hz. Two blinded cardiologists independently analyzed the pre-ECV ECG. First they confirmed whether the ECG showed atrial fibrillation (AF) and then classified it as either fine or coarse based on the fibrillatory wave (Fw) amplitude. Fw were fine (fFw) if the maximal amplitude was < 0.1 mV and coarse (cFw) if maximal deflection ≥ 0.1 mV as described classically (Peter et al., 1966). Fw were examined in leads II and V_1 using callipers on standard ECG paper. When there was disagreement regarding the classification, a third cardiologist's opinion was sought as final arbiter. Post-ECV ECGs were obtained 4 hr after ECV, before discharge from hospital and at 6 weeks after ECV at follow-up appointment. These were analyzed by two independent cardiologists to ascertain if they were in sinus rhythm or AF, blinded to pre-ECV ECGs.

2.2 | ECV procedure

All patients underwent elective day-case ECV under the supervision of a cardiologist and anesthetist. ECGs were obtained prior to the procedure to confirm AF. After initiation of appropriate monitoring as prescribed by AAGBI standards, induction of anesthesia was achieved by inhaled sevoflurane. The airway was secured by insertion of a laryngeal mask airway. No routine adjunctive anti-arrhythmic medication was given periprocedure. ECV was performed using external thoracic direct current synchronized biphasic shock with pads in an

FIGURE 2 Study flowchart. * χ^2 p -value for difference between cFw and fFw groups .006. ECV: electrical cardioversion; cFw: coarse fibrillatory waves; fFw: fine fibrillatory waves; SR: sinus rhythm

anterolateral position. Starting energy was 150J, or 200J for patients over 100 kg. If the shock failed to convert the rhythm to SR or if the rhythm reverted back to AF immediately, further shocks were delivered at 200J and then 360J, up to a maximum of three shocks. Acute success was defined as an ECG showing SR 4 hr post procedure, before hospital discharge.

2.3 | Statistical analysis

We estimated a sample size of 31 per arm (62 in total) would be needed to provide 80% power ($p < .05$ single sided) to detect a 30% change in the primary endpoint between groups (Pocock, 1983). Continuous results are presented as mean $\pm$ standard deviation and categorical data as counts or percentages. Analysis and comparisons of continuous data were performed using ANOVA, while the χ^2 test was used to compare categorical data. Fisher's exact test was used if χ^2 assumptions were not met. A two-sided probability level of $<.05$ was considered significant. Multivariate models for prediction of ECV success included terms with p value of $<.1$ at univariate analysis along with Fw type. All calculations were performed using SPSS 20.0 (IBM Software, Armonk, NY, USA).

3 | RESULTS

One hundred and thirty-eight ECVs occurred during the 8-months period. 11 sets of notes were unavailable or incomplete and 15 ECVs were for atrial flutter and excluded. Therefore, 112 ECVs for atrial fibrillation (AF) were analyzed. Of these ECVs there were 94 individual

patients (51 male, 43 female). One patient had 4 ECVs and 15 patients had 2 ECVs. Each patient was individually analyzed and only their first ECV was included in the analysis. (Figure 2).

Overall, the mean patient age was 71.6 ± 9.3 years. Twenty-three patients (24%) had ischemic heart disease, 26 patients (28%) had clinical heart failure, 22 patients (23%) had diabetes mellitus, and 14 patients (15%) smoked. One patient had undergone a previous AF ablation and 18 patients (19%) had undergone previous ECVs. Eighty patients (85%) were on beta-blockers, 16 patients (17%) were on digoxin, 12 patients (13%) were on amiodarone, 4 patients (4%) were on calcium channel blockers, and 1 patient was on flecainide. We found that 26 patients (28%) had a defined date of onset with the mean duration of AF being 2 ± 1.3 years.

3.1 | Fibrillatory waves

All ECGs of the 94 ECVs included were analyzed. Seventeen had coarse fibrillation waves (cFW) in lead V_1 only, seven had cFW in lead II only, and eight had cFW in both leads. Therefore, 32 (34%) had cFW in a single or both leads. There was 98% agreement between the two cardiologists in defining Fw as either coarse or fine and disagreement in only 2 (2%) ECGs. Baseline demographics and echocardiography data for cFw and fFw groups are detailed in Table 1. There were no significant differences.

There was high rate of acute success of ECV, with 90 (96%) of patients being in SR on discharge ECG. There was no difference in the maximal energy used between cFw and fFw groups ($190J \pm 45$ vs. $203J \pm 45$, $p = .23$) or the number of shocks required (1.1 ± 0.2 vs. 1.2 ± 0.4 , $p = .24$). Figure 2 depicts acute and 6 weeks success of ECV

Variable	Fine F waves (n = 62)	Coarse F waves (n = 32)	p-value for difference
Male—number (%)	31 (50)	20 (63)	.25
Age—years (SD)	71.9 (9.5)	71 (8.9)	.71
BMI—kg/m ² (SD)	33.4 (8.9)	32.9 (8.5)	.81
Duration AF unknown—number (%)	44 (71)	24 (72)	.81
Mean duration if known—years (SD)	2 (1.6)	2 (0.9)	1.00
Previous ECV—number (%)	15 (24)	3 (9)	.10
β-blocker—number (%)	50 (81)	30 (94)	.13
Amiodarone—number (%)	10 (16)	2 (6)	.21
Ca ²⁺ Channel blocker—number (%)	4 (6)	0	.30
Digoxin—number (%)	13 (21)	3 (9)	.25
Flecainide—number (%)	1 (2)	0	1.00
LA size—cm (SD)	4.5 (0.57)	4.4 (0.53)	.36
Indexed LA volume—mls/m ² (SD)	38.9 (12.9)	41.9 (11.2)	.34
Normal LV function—number (%)	37 (59.6)	18 (56.2)	.98

AF, atrial fibrillation; BMI, body mass index; ECV, electrical cardioversion; LA, left atrium; LV, left ventricle; SD, standard deviation.

stratified by Fw subtype. At 6 weeks, in the cFw group, 75% of patients maintained SR vs. 40% in the fFw group (χ^2 , $p = .006$) with the odds ratio (OR) of maintaining SR at 6 weeks in the presence of cFw being 3.5 [95% confidence interval (CI): 1.4–8.9, $p = .007$]. After the exclusion from both groups of patients taking amiodarone at baseline, the OR of maintaining SR at 6 weeks in the presence of cFw was 3.7 (95% CI: 1.4–9.7, $p = .007$). Across the overall study population, there were no other significant univariate predictors of SR at 6 weeks post-ECV based on standard variables we collected so further multivariate analysis was not performed (Table 2).

4 | DISCUSSION

Our results show that fibrillatory waves can be easily seen and categorized on 12-lead surface ECGs of patients in AF into coarse (cFw) and fine (fFw) varieties. Our data suggest that the presence of coarse F waves is the strongest predictor of maintenance of SR at 6 weeks after ECV, independent of traditional risk factors.

The prevalence of cFw (in either or both leads II or V₁) in our cohort was 34%, correlating well with previous observational data from other studies in selected patients with AF (Nault et al., 2009; Thurman & Janney, 1962). Previous work has suggested that Fw amplitude may correlate inversely with duration of AF (Nault et al., 2009; Yamamoto et al., 2005) and although we were unable to replicate this finding, we only had data regarding a “clear” onset of AF in 28% of patients whilst other groups studied patients later in their disease course with differences between groups in AF duration measured in years. We also did not find any correlation between cFw and left atrial size or presence of valvular disease as was suggested in the early descriptions of F-waves

TABLE 1 Baseline characteristics of groups

TABLE 2 Univariate predictors of sinus rhythm 6 weeks postelectrical cardioversion

	Univariate		
	Odds ratio	95% CI	p-value
Age	1.0	0.9–1.1	.63
Male gender	0.7	0.3–1.5	.66
BMI	1.0	0.9–1.0	.99
Mean duration AF	0.8	0.5–1.5	.84
Previous ECV	0.9	0.3–2.5	.84
LA size	1.6	0.7–3.4	.22
Indexed LA volume	1.0	1.0–1.1	.13
LV function			
Normal (reference)	1.0		
Mildly impaired vs. normal	1.8	0.7–4.9	.25
Moderately impaired vs. normal	1.2	0.3–5.0	.80
Severely impaired vs. normal	0.6	0.1–4.1	.64
Amiodarone use	2.0	0.6–71	.29
Coarse F waves	3.5	1.4–8.9	.007

AF, atrial fibrillation; BMI, body mass index; CI, confidence interval; ECV, electrical cardioversion; LA, left atrium; LV, left ventricle.

(Peter et al., 1966; Thurman & Janney, 1962) or in more recent publications (Nault et al., 2009; Yamamoto et al., 2005). This may be explained due to the lengthier durations of AF experienced by those with fFw in other cohorts leading to structural remodeling. Indeed, other

studies have specifically refuted the concept that fFw are associated with increased atrial size (Morganroth, Horowitz, Josephson, & Kastor, 1979; Mutlu et al., 2003). Our results were also independent of pharmacotherapy and specifically, amiodarone use.

Intuitively, the morphology of the F waves on a surface ECG ought to come from an interplay between viable atrial muscle mass and any underlying mechanisms of AF. In one study, biatrial mapping revealed that 87% of patients with cFw on surface ECG upon AF induction in the laboratory had discrete and organized endocardial atrial electrograms whilst 88% of those with fFw showed a chaotic pattern (Saksena et al., 1999). Whilst the specific electrophysiological mechanisms leading to persistent AF continue to be investigated, data has already suggested the presence of cFw as a marker of acute success of catheter ablation in persistent AF (Nault et al., 2009; Zarzoso et al., 2016). Given that large-scale trials of established methods for invasive substrate modification for persistent AF have not been convincing in terms of efficacy and that "early" modification of risk factors improves AF burden and symptoms (Abed et al., 2013), using clinical response to ECV as a marker for those selected people who may benefit from a rhythm control strategy is increasingly relevant. To that end, our study is the first to show that a simple, reproducible clinical measurement reflecting a complex underlying pathophysiological process could be a useful marker of procedural success.

Our data are limited by the fact we do not have longer follow-up. From a clinical point of view, however, if a patient can maintain SR at 6 weeks post-ECV and has sufficient time to notice a symptomatic benefit, this may encourage a more invasive rhythm control strategy to be pursued. We did not use complex electronic methods to determine F-wave amplitude as we felt this would not be reproducible in day-to-day clinical practice. A previous study using computerized software showed that maximal Fw amplitudes of 0.07 mV provided optimum values to maximize sensitivity and specificity in terms of prediction of acute AF termination by catheter ablation (Nault et al., 2009) which is similar to the 0.1 mV surface ECG definition which has been used as a "standard" previously.

In summary, coarse fibrillatory wave activity identified simply on surface ECGs predicted maintenance of SR at 6 weeks after ECV for persistent AF, independent of traditional risk factors. This may be a simple and noninvasive adjunctive marker reflecting complex substrate dynamics, which may be useful to lend weight to the pursuit of an individualized rhythm control strategy for patients with persistent AF.

ORCID

Parag R. Gajendragadkar <http://orcid.org/0000-0003-3312-0183>

REFERENCES

- Abed, H. S., Wittert, G. A., Leong, D. P., Shirazi, M. G., Bahrami, B., Middeldorp, M. E., ... Abhayaratna, W. P. (2013). Effect of weight reduction and cardiometabolic risk factor management on symptom burden and severity in patients with atrial fibrillation: A randomized clinical trial. *JAMA*, 310(19), 2050–2060. <https://doi.org/10.1001/jama.2013.280521>
- Blackshear, J. L., Safford, R. E., & Pearce, L. A. (1996). F-amplitude, left atrial appendage velocity, and thromboembolic risk in nonrheumatic atrial fibrillation. Stroke Prevention in Atrial Fibrillation Investigators. *Clinical Cardiology*, 19(4), 309–313. <https://doi.org/10.1002/clc.4960190406>
- Grönberg, T., Hartikainen, J. E. K., Nuotio, I., Biancari, F., Vasankari, T., Nikkinen, M., ... Airaksinen, K. J. (2015). Can we predict the failure of electrical cardioversion of acute atrial fibrillation? The FinCV study. *Pacing and Clinical Electrophysiology: PACE*, 38(3), 368–375. <https://doi.org/10.1111/pace.12561>
- Holmqvist, F., Stridh, M., Waktare, J. E. P., Roijer, A., Sörnmo, L., Platonov, P. G., & Meurling, C. J. (2006). Atrial fibrillation signal organization predicts sinus rhythm maintenance in patients undergoing cardioversion of atrial fibrillation. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*, 8(8), 559–565. <https://doi.org/10.1093/europace/eul072>
- Kirchhof, P., Benussi, S., Kotecha, D., Ahlsson, A., Atar, D., Casadei, B., ... Hindricks, G. (2016). 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS. *European Heart Journal*, 37(38), 2893–2962. <https://doi.org/10.1093/eurheartj/ehw210>
- Morganroth, J., Horowitz, L. N., Josephson, M. E., & Kastor, J. A. (1979). Relationship of atrial fibrillatory wave amplitude to left atrial size and etiology of heart disease. An old generalization re-examined. *American Heart Journal*, 97(2), 184–186. [https://doi.org/10.1016/0002-8703\(79\)90354-5](https://doi.org/10.1016/0002-8703(79)90354-5)
- Mutlu, B., Karabulut, M., Eroglu, E., Tigen, K., Bayrak, F., Fotbolcu, H., & Basaran, Y. (2003). Fibrillatory wave amplitude as a marker of left atrial and left atrial appendage function, and a predictor of thromboembolic risk in patients with rheumatic mitral stenosis. *International Journal of Cardiology*, 91(2–3), 179–186. [https://doi.org/10.1016/S0167-5273\(03\)00024-X](https://doi.org/10.1016/S0167-5273(03)00024-X)
- Nault, I., Lellouche, N., Matsuo, S., Knecht, S., Wright, M., Lim, K.-T., ... Derval, N. (2009). Clinical value of fibrillatory wave amplitude on surface ECG in patients with persistent atrial fibrillation. *Journal of Interventional Cardiac Electrophysiology: an International Journal of Arrhythmias and Pacing*, 26(1), 11–19. <https://doi.org/10.1007/s10840-009-9398-3>
- Peter, R. H., Morris, J. J., & McIntosh, H. D. (1966). Relationship of fibrillatory waves and P waves in the electrocardiogram. *Circulation*, 33(4), 599–606. <https://doi.org/10.1161/01.CIR.33.4.599>
- Pocock, S. J. (1983). *Clinical trials: A practical approach*. Oxford: Wiley.
- Raitt, M. H., Volgman, A. S., Zoble, R. G., Charbonneau, L., Padder, F. A., O'Hara, G. E., ... Investigators, A. F. F. I. R. M. (2006). Prediction of the recurrence of atrial fibrillation after cardioversion in the Atrial Fibrillation Follow-up Investigation of Rhythm Management (AFFIRM) study. *American Heart Journal*, 151(2), 390–396. <https://doi.org/10.1016/j.ahj.2005.03.019>
- Saksena, S., Giorgberidze, I., Mehra, R., Hill, M., Prakash, A., Krol, R. B., & Mathew, P. (1999). Electrophysiology and endocardial mapping of induced atrial fibrillation in patients with spontaneous atrial fibrillation. *The American Journal of Cardiology*, 83(2), 187–193. [https://doi.org/10.1016/S0002-9149\(98\)00822-4](https://doi.org/10.1016/S0002-9149(98)00822-4)
- Saksena, S., Skadsberg, N. D., Rao, H. B., & Filipecki, A. (2005). Biatial and three-dimensional mapping of spontaneous atrial arrhythmias in patients with refractory atrial fibrillation. *Journal of Cardiovascular Electrophysiology*, 16(5), 494–504. <https://doi.org/10.1111/j.1540-8167.2005.40531.x>
- Siaplaouras, S., Jung, J., Buob, A., & Heisel, A. (2004). Incidence and management of early recurrent atrial fibrillation (ERAF) after transthoracic electrical cardioversion. *Europace: European Pacing, Arrhythmias, and*

- Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*, 6(1), 15–20. <https://doi.org/10.1016/j.eupc.2003.09.010>
- Thurman, M., & Janney, J. G. (1962). The diagnostic importance of fibrillatory wave size. *Circulation*, 25, 991–994. <https://doi.org/10.1161/01.CIR.25.6.991>
- Van Gelder, I. C., Crijns, H. J., Van Gilst, W. H., Verwer, R., & Lie, K. I. (1991). Prediction of uneventful cardioversion and maintenance of sinus rhythm from direct-current electrical cardioversion of chronic atrial fibrillation and flutter. *The American Journal of Cardiology*, 68(1), 41–46. [https://doi.org/10.1016/0002-9149\(91\)90707-R](https://doi.org/10.1016/0002-9149(91)90707-R)
- Xi, Q., Sahakian, A. V., Ng, J., & Swiryn, S. (2004). Atrial fibrillatory wave characteristics on surface electrogram: ECG to ECG repeatability over twenty-four hours in clinically stable patients. *Journal of Cardiovascular Electrophysiology*, 15(8), 911–917. <https://doi.org/10.1046/j.1540-8167.2004.03577.x>
- Yamamoto, S., Suwa, M., Ito, T., Murakami, S., Umeda, T., Tokaji, Y., ... Kitaura, Y. (2005). Comparison of frequency of thromboembolic events and echocardiographic findings in patients with chronic nonvalvular atrial fibrillation and coarse versus fine electrocardiographic fibrillatory waves. *The American Journal of Cardiology*, 96(3), 408–411. <https://doi.org/10.1016/j.amjcard.2005.03.087>
- Zarzoso, V., Latcu, D. G., Hidalgo-Muñoz, A. R., Meo, M., Meste, O., Popescu, I., & Saoudi, N. (2016). Non-invasive prediction of catheter ablation outcome in persistent atrial fibrillation by fibrillatory wave amplitude computation in multiple electrocardiogram leads. *Archives of Cardiovascular Diseases*, 109(12), 679–688. <https://doi.org/10.1016/j.acvd.2016.03.002>
- Zohar, P., Kovacic, M., Brezocnik, M., & Podbregar, M. (2005). Prediction of maintenance of sinus rhythm after electrical cardioversion of atrial fibrillation by non-deterministic modelling. *Europace: European Pacing, Arrhythmias, and Cardiac Electrophysiology: Journal of the Working Groups on Cardiac Pacing, Arrhythmias, and Cardiac Cellular Electrophysiology of the European Society of Cardiology*, 7(5), 500–507. <https://doi.org/10.1016/j.eupc.2005.04.007>

How to cite this article: Zhao TX, Martin CA, Cooper JP, Gajendragadkar PR. Coarse fibrillatory waves in atrial fibrillation predict success of electrical cardioversion. *Ann Noninvasive Electrocardiol*. 2018;23:e12528. <https://doi.org/10.1111/anec.12528>