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ORIGINAL RESEARCH

IMAGING

ECG and Atrial Appendage Doppler Discordance Is Common in Patients Undergoing Cardiac Surgery

Prospective Study

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ABSTRACT

BACKGROUND Patients with atrial fibrillation (AF) remain at increased risk of thromboembolism despite apparent maintenance of sinus rhythm with the cause often attributed to periods of asymptomatic AF. Atrial mechanical discordance, with the body of the left atrium (LA) in sinus rhythm and the left atrial appendage (LAA) in AF may also be a contributor.

OBJECTIVES The purpose of this study was to assess the frequency of electrocardiogram (ECG) rhythm and LAA and/right atrial appendage (RAA) Doppler ejection phenotype (transesophageal echocardiography [TEE]) discordance in patients undergoing cardiac surgery.

METHODS A total of 124 patients undergoing coronary artery bypass graft (CABG), CABG and valve surgery, or isolated valve repair or replacement (valve ± CABG) were prospectively studied. Intraoperative surface ECG rhythm strip and TEE were performed before cardiopulmonary bypass. The ECG and TEE LAA/RAA Doppler spectrum were independently classified as sinus or AF.

RESULTS Of 107 patients (age 65 ± 12 years; 31% female; 65% CABG, 31% valve ± CABG) without a history of AF, 39 (36%) had ECG and LAA and/or RAA discordance (ECG/LAA Doppler discordance, n = 12 [11%]; ECG/RAA Doppler discordance, n = 35 [33%]). There was no significant difference between concordant and discordant groups with regard to age, gender, history of hypertension, diabetes, heart failure, or stroke (all $P > 0.05$).

CONCLUSIONS A large minority of patients without a history of AF undergoing cardiac surgery have ECG/atrial appendage Doppler discordance, a setting that may promote thromboembolism in non-anticoagulated patients. Clinical parameters do not identify patients at increased risk for discordance. (JACC Adv 2024;3:100977) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

CABG = coronary artery bypass graft

LAA = left atrial appendage

POAF = postoperative atrial fibrillation

RAA = right atrial appendage

TEE = transesophageal echocardiography

Patients with atrial fibrillation (AF) remain at increased risk for thromboembolism despite apparent maintenance of sinus rhythm (SR).[1,2] The etiology of these adverse events has commonly been ascribed to periods of asymptomatic AF during which thrombus forms in the left atrial appendage (LAA). In patients with AF, the vast majority of thrombi are identified in the LAA.[3] Case report and retrospective nonoperative transesophageal echocardiography (TEE) studies have demonstrated mechanical discordance between the body of the left atrium (LA) (sinus phenotype) and LAA (eg, Doppler AF phenotype) using TEE.[4,5] Moreover, among AF patients undergoing percutaneous LAA electrical isolation, ECG SR and TEE evidence of LAA AF Doppler phenotype is common and is associated with increased stroke risk.[6]

Patients referred for cardiac surgery are at high risk of postoperative AF (POAF),[7,8] suggesting their atrial myocardial substrate is vulnerable to AF.[9] We hypothesized that discordance between the surface ECG rhythm and LAA/or right atrial appendage (RAA) Doppler ejection phenotype would be common among patients undergoing coronary surgery and sought to prospectively determine the prevalence in this population.

METHODS

POPULATION AND DATA COLLECTION. Patients undergoing coronary artery bypass graft (CABG), CABG and valve surgery, or isolated valve repair or replacement (valve ± CABG), or aortic repair were prospectively studied. The study was approved by the institution's investigational review board which waived written informed consent. Clinical decisions of surgical referral and treating management were made by physicians blinded to the discordance data.

Intraoperative surface ECG rhythm strip and TEE were performed while the patient was under general anesthesia prior to cardiopulmonary bypass. Multiplane TEE was performed (X7-2t transducer, Philips Healthcare) as previously described.[5] Pulse-Doppler was acquired from 1 cm into the orifice of LAA at 0°, and 90°, and 1 cm into the orifice of RAA at 135°. Offline software (EchoPAC, version 202, General Electric Healthcare) was used to analyze the Doppler patterns. The TEE LAA and RAA Doppler were independently visually classified as SR or AF by 2 investigators (W.J.M. and Q.Z.C.) blinded to the patients' outcomes and ECG. Disagreements were decided by consensus review blinded to the ECG data. LAA/RAA Doppler AF phenotype was defined by an irregular deflection of viable beat-to-beat velocity.[10] ECG AF pattern was defined as absence of P-wave and irregular R-R intervals. The LAA width and depth were measured as previously described,[5] and RAA width and depth were measured at 135°. The patient's electronic medical record was reviewed to determine the incidence of preoperative and POAF.

STATISTICAL METHODS. Statistical analyses were performed with SPSS (version 20.0, International Business Machines, Inc). Continuous variables are reported as mean ± SD and categorical variables as frequency (percentage). For categorical variables, a 2-tailed chi-square or Fisher exact test was conducted between the groups with and without discordance. For continuous variables, comparisons between groups were performed using 2-tailed *t*-tests if normally distributed or using the Mann-Whitney test if not normally distributed. A statistical level of $P \leq 0.05$ was considered significant.

RESULTS

Of the 124 patients who underwent cardiac surgery, 17 had a history of AF (including 8 patients who were in ECG AF pre-bypass and 9 with a history of AF). The remaining 107 included 70 (65%) patients who underwent CABG, 33 (31%) patients who underwent valve ± CABG, 3 patients who underwent aortic repair, and 1 patient who underwent left atrial myxoma excision. The clinical characteristics of the study population are summarized in **Table 1**.

A total of 39 (36%) patients demonstrated electrical-mechanical discordance, 4 (4%) patients with isolated discordant LAA Doppler AF phenotype (**Central Illustration**), 27 (25%) with isolated RAA Doppler AF phenotype, and 8 (7%) with discordance in both the LAA and the RAA. There was no significant difference in concordant and discordant groups with regard to hypertension, diabetes, heart failure, stroke, coronary artery disease, $CHADS_2$ score, or CHA_2DS_2-VASc score (all $P > 0.05$). In addition, the appendage sizes were similar (**Table 2**). Lower LAA peak ejection velocity was found in patients with ECG-SR/LAA-AF discordance ($P = 0.035$). No significant difference was found in LAA or RAA sizes between groups (all $P > 0.05$).

POAF occurred in 33 (31%) patients. There was a trend for increased POAF in the discordant group

TABLE 1 Clinical Characteristics of the Study Population

		ECG and LAA Discordance			ECG and LAA or RAA Discordance		
	Entire Cohort	ECG-SR/LAA Concordant	ECG-SR/LAA Discordant	*P* Value	ECG-SR/LAA-RAA Concordant	ECG-SR/LAA-RAA Discordant	*P* Value
All patients, n	107	95 (89.0)	12 (11.0)		68 (64.0)	39 (36.0)	
Age, y	65 ± 12	66 ± 11	64 ± 15	0.60	65 ± 11	66 ± 13	0.58
Female, %	31	34	8	0.064	29	33	0.67
Hypertension,%	71	72	66	0.74	69	74	0.57
Diabetes mellitus, %	34	34	33	1.00	31	39	0.43
HFpEF, %	13	12	17	0.66	12	15	0.59
HFrEF, %	14	15	8	1.00	15	13	0.79
Stroke/TIA, %	8	6	17	0.22	6	10	0.46
CAD, %	79	78	92	0.45	78	82	0.61
$CHADS_2$	1.8 (1.3)	1.8 (1.3)	1.9 (1.6)	0.83	1.7 (1.3)	2.1 (1.4)	0.47
CHA_2DS_2-VASc	4.0 (2.0)	4.0 (2.0)	3.8 (1.9)	0.81	3.9 (1.9)	4.2 (2.6)	0.46
CABG patients, n	70	61 (87.0)	9 (13.0)		44 (63.0)	26 (37.0)	
Age, y	64 ± 11	64 ± 11	64 ± 15	0.84	64 ± 10	64 ± 14	0.92
Female, %	27	30	11	0.47	23	35	0.28
Hypertension,%	76	75	78	0.88	71	85	0.25
Diabetes mellitus, %	40	39	44	0.77	36	46	0.42
HFpEF,%	14	5	11	0.43	2	12	0.14
HFrEF, %	6	15	11	1.00	14	15	0.84
Stroke/TIA, %	6	5	11	0.43	5	8	0.62
CAD, %	-	-	-		-	-	
$CHADS_2$	1.8 (1.4)	1.8 (1.3)	2.0 (1.8)	0.69	1.6 (1.3)	2.2 (1.5)	0.11
CHA_2DS_2-VASc	4.2 (1.9)	4.2 (1.9)	4.1 (2.0)	0.90	4.0 (1.8)	4.5 (2.1)	0.80
Valve ± CABG patients, n	33	30 (91.0)	3 (9.0)		21 (64.0)	12 (36.0)	
Age, y	69 ± 11	69 ± 10	64 ± 18	0.47	68 ± 10	69 ± 12	0.91
Female, %	36	40	0	0.28	46	25	0.31
Hypertension,%	64	67	33	0.54	71	50	0.22
Diabetes mellitus, %	24	27	0	0.56	24	25	0.94
HFpEF, %	15	30	33	1.00	33	25	0.71
HFrEF, %	30	17	0	1.00	19	8	0.63
Stroke/TIA, %	9	7	33	0.26	5	17	0.25
CAD, %	46	43	66	0.58	42	50	0.69
$CHADS_2$	1.9 (1.2)	2.0 (1.2)	1.7 (1.2)	0.68	2.0 (1.1)	1.8 (1.3)	0.70
CHA_2DS_2-VASc	3.6 (2.1)	3.7 (2.2)	3.0 (1.7)	0.59	3.8 (2.2)	3.3 (2.1)	0.46

Values are n (%) or mean ± SD unless otherwise indicated.

CABG = coronary artery bypass grafting; CAD = coronary artery disease; ECG = surface electrocardiography; HFpEF = heart failure with preserved ejection fraction; HFrEF = heart failure with reduced ejection fraction; LAA = left atrial appendage; RAA = right atrial appendage; TIA = transient ischemic attack.

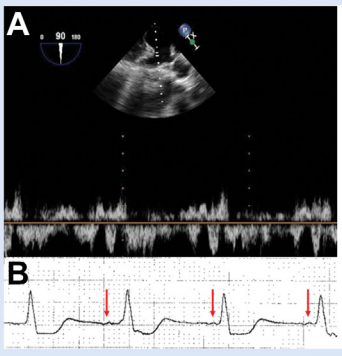
(41% vs 25%, $P = 0.082$). In the subgroup undergoing CABG, more discordant patients developed POAF (39% vs 16%, $P = 0.032$) and hospitalization stay was prolonged ($P = 0.015$).

DISCUSSION

In the prospective intraoperative TEE study of atrial electrical and mechanical discordance in patients undergoing cardiac surgery without prior AF, we found: 1) surface ECG and appendage Doppler discordance is common (11% for LAA); 2) clinical parameters do not predict discordance; and 3) discordance is increased among those who developed POAF, especially in patients undergoing CABG.

Prior case report[4] and retrospective nonoperative TEE series[5] have reported atrial electrical-mechanical discordance. We previously reported on a retrospectively identified 208 consecutive patients undergoing TEE by a single provider and found LAA discordance in 8% of patients. A slightly higher (11%) proportion of ECG-SR/LAA-AF phenotype discordance was found in the present study.[5] The slightly increased prevalence in the current study is likely attributable to the

CENTRAL ILLUSTRATION **Discordance Between the Surface Electrocardiogram and the Transesophageal Atrial Appendage Doppler Rhythm Phenotype in Patients Undergoing Cardiac Surgery**



Intraoperative surface electrocardiograms (ECG) and transesophageal echocardiograms (TEE) were prospectively obtained in 124 patients before cardiopulmonary surgery.

Electrical-mechanical discordance was defined as the difference between the ECG rhythm (body of the left atrium) and the TEE atrial appendage rhythm phenotype.

Results

- 36% of patients without atrial fibrillation (AF) had electrical-mechanical discordance between the surface ECG rhythm and atrial appendage Doppler waveform phenotype
- 31% of patients developed postoperative AF
- A trend was seen between postoperative AF and ECG-TEE findings (41% AF in patients with discordant ECG-TEE vs 25% in patients with concordant ECG-TEE, $P = 0.082$)

Conclusion

Atrial electrical-mechanical discordance is common in patients undergoing cardiac surgery and may help explain thromboembolism in patients with ECG sinus rhythm.

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(A) Transesophageal echocardiogram left atrial appendage waveform with the pulsed Doppler sample volume at the mouth of the left atrial appendage in a patient with left atrial appendage Doppler atrial fibrillation pattern and (B) Surface electrocardiogram (ECG) rhythm strip demonstrating sinus rhythm (red arrows: p-wave). The ECG AF pattern was defined as absence of P-wave and irregular R-R intervals. The LAA/RAA Doppler AF phenotype was defined by an irregular deflection of viable beat-to-beat velocity. AF = atrial fibrillation; LAA = left atrial appendage.

different study populations as the prior group were heterogeneous patients referred for TEE while subjects in the present prospective study were undergoing cardiac surgery and presumably have a myocardial substrate more vulnerable to AF.[9] In addition, the previous study used mitral valve motion as a surrogate for rhythm as the surface ECG rhythm strip was not independently recorded. In the current study, we independently compared the surface ECG rhythm with atrial appendage Doppler phenotype, providing more clinically relevant information.

The LAA/RAA mechanical contraction pattern can be readily characterized using pulsed wave Doppler. A study focusing on SR patients 6-month after percutaneous electrical LAA isolation similarly used TEE LAA Doppler to assess LAA mechanical function.[6] Stroke was more common in the group with LAA mechanical dysfunction irrespective of CHA_2DS_2-VASc score. This is consistent with our study which demonstrated patients with discordance at *higher* risk of POAF despite *similar* CHA_2DS_2-VASc scores.

The adverse consequences of POAF have been well documented and include increased length of stay, long-term risk of stroke and death.[11,12] As POAF most commonly occurs within 4 days of surgery,[13] early identification of patients at high risk of POAF and

TABLE 2 Transesophageal Echocardiography Metrics in the Study Population

		ECG and LAA Discordance			ECG and LAA or RAA Discordance		
	Entire Cohort	ECG-SR/LAA Concordant	ECG-SR/LAA Discordant	*P* Value	ECG-SR/LAA-RAA Concordant	ECG-SR/LAA-RAA Discordant	*P* Value
All patients, n	107	95 (89.0)	12 (11.0)		68 (64.0)	39 (36.0)	
LAA width 0°, cm	1.8 ± 0.4	1.8 ± 0.4	1.7 ± 0.5	0.32	1.9 ± 0.4	1.8 ± 0.5	0.35
LAA depth 0°, cm	2.7 ± 0.6	2.7 ± 0.6	2.6 ± 0.9	0.42	2.7 ± 0.6	2.7 ± 0.7	0.67
RAA width 135°, cm	3.4 ± 0.7	3.4 ± 0.8	3.1 ± 0.4	0.25	3.4 ± 0.8	3.3 ± 0.6	0.61
RAA depth 135°, cm	1.5 ± 0.4	1.4 ± 0.4	1.5 ± 0.5	0.46	1.5 ± 0.4	1.4 ± 0.4	0.36
LAA ejection velocity, cm/s	36.4 ± 12.9	37.3 ± 13.1	29.0 ± 9.3	0.035	38.2 ± 12.5	33.2 ± 13.3	0.052
RAA ejection velocity, cm/s	33.7 ± 13.2	33.7 ± 12.7	34.2 ± 17.4	0.91	34.3 ± 13.1	32.8 ± 13.5	0.58
CABG patients, n	70	61 (87.0)	9 (13.0)		44 (63.0)	26 (37.0)	
LAA width 0°, cm	1.8 ± 0.4	1.8 ± 0.4	1.5 ± 0.4	0.063	1.8 ± 0.4	1.7 ± 0.4	0.11
LAA depth 0°, cm	2.7 ± 0.6	2.7 ± 0.6	2.6 ± 1.1	0.71	2.6 ± 0.5	2.7 ± 0.7	0.57
RAA width 135°, cm	3.3 ± 0.6	3.4 ± 0.8	3.0 ± 0.4	0.30	3.4 ± 0.8	3.2 ± 0.6	0.43
RAA depth 135°, cm	1.5 ± 0.4	1.5 ± 0.4	1.7 ± 0.6	0.19	1.5 ± 0.4	1.6 ± 0.5	0.83
LAA ejection velocity, cm/s	34.3 ± 10.8	34.9 ± 10.9	30.0 ± 9.8	0.20	35.6 ± 10.6	32.0 ± 10.9	0.18
RAA ejection velocity, cm/s	34.3 ± 14.3	33.8 ± 13.7	37.4 ± 18.5	0.49	34.1 ± 14.1	34.7 ± 14.9	0.89
Valve ± CABG patients, n	33	30 (91.0)	3 (9.0)		21 (64.0)	12 (36.0)	
LAA width 0°, cm	1.9 ± 0.4	1.9 ± 0.4	2.1 ± 0.4	0.74	2.0 ± 0.4	1.9 ± 0.4	0.73
LAA depth 0°, cm	2.8 ± 0.7	2.8 ± 0.7	2.6 ± 0.2	0.55	3.0 ± 0.7	2.5 ± 0.5	0.046
RAA width 135°, cm	3.4 ± 0.7	3.4 ± 0.8	3.3 ± 0.3	0.82	3.5 ± 0.6	3.4 ± 0.8	0.71
RAA depth 135°, cm	1.4 ± 0.3	1.4 ± 0.3	1.2 ± 0.9	0.35	1.5 ± 0.4	1.3 ± 0.2	0.26
LAA ejection velocity, cm/s	40.7 ± 15.8	42.2 ± 15.6	26.0 ± 8.7	0.090	43.3 ± 14.1	36.2 ± 18.0	0.22
RAA ejection velocity, cm/s	32.4 ± 10.6	33.3 ± 10.5	24.3 ± 10.0	0.32	34.4 ± 10.9	29.4 ± 9.8	0.21

Values are n, n (%), or mean ± SD.

CABG = coronary artery bypass grafting; ECG = surface electrocardiography; LAA = left atrial appendage; RAA = right atrial appendage; SR = sinus rhythm.

applying perioperative intervention may benefit their outcome. We found discordance nearly doubled the rate of POAF, particularly in the CABG subgroup. The American Society of Anesthesiologists recommends TEE in all patients undergoing a cardiac or thoracic aortic surgical procedure.[14] During the routine perioperative TEE, LAA/RAA appendage rhythm and velocity acquisition can easily be performed, thereby allowing for identification of discordance, with minimal burden or cost.

Consistent with our prior retrospective study,[5] we found lower LAA ejection velocities in ECF-SR/LAA discordant patients. Depressed LAA velocity is associated with spontaneous echo contrast, another marker of stasis and more common in patients with stroke independent of the underlying rhythm.[6,15] We did not assess spontaneous echo contrast.

STUDY LIMITATIONS. Although prospective, our study population is relatively small and the presence of preoperative and POAF were based on review of the electronic medical records. No independent long-term monitoring for AF was performed. The study was intended to describe the prevalence of discordance and was not powered to examine discordance on POAF. Based on our findings, a large multicenter study with a broader population focusing on the prognostic value of discordance in predicting POAF appears justified. Our population is largely Caucasian. Our findings may not be applicable to other groups. However, the occurrence of POAF in our study is consistent with prior large diverse populations.[7,8] While LAA Doppler phenotypes are well defined and Doppler profiles readily obtained, RAA Doppler profiles are less well defined and RAA Doppler is more difficult to obtain.

CONCLUSIONS

A large minority of patients undergoing cardiac surgery demonstrate discordance between the surface ECG and the LAA-RAA mechanical phenotype. Among patients undergoing CABG, discordance is associated with POAF. Future studies are needed to examine the role of intervention in the discordant population to prevent POAF and potential role of anticoagulation

for stroke prevention among those with ECG sinus and appendage mechanical fibrillation.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: In a large minority of patient undergoing cardiac surgery without a prior history of AF, transesophageal Doppler echocardiography demonstrates an AF atrial appendage phenotype, despite SR on the surface electrocardiogram.

TRANSLATIONAL OUTLOOK: These findings identify a novel mechanism for stroke in the absence of electrocardiographic AF.

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KEY WORDS atrial fibrillation, atrial mechanics, discordance, electrocardiogram, transesophageal echocardiography