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Left atrial, pulmonary vein, and left atrial appendage anatomy in Indigenous individuals: Implications for atrial fibrillation

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ABSTRACT

Background: Indigenous Australians experience a greater burden of AF. Whether this is in-part due to differences in arrhythmogenic structures that appear to contribute to AF differences amongst other ethnicities is not known.
Methods: We studied forty individuals matched for ethnicity and other AF risk factors. Computed tomography imaging was used to characterise left atrial (LA), pulmonary vein (PV), and left atrial appendage (LAA) anatomy.
Results: There were no significant differences in LA diameters or volumes between Indigenous and non-Indigenous Australians. Similarly, we could not detect any consistent differences in PV number, morphology, diameters, or ostial characteristics according to ethnicity. LAA analyses suggested that Indigenous Australians may have a greater proportion of non chickenwing LAA type, and a tendency for eccentric, oval-shaped LAA ostia; however, there were no other differences seen with regards to LAA volume or depth. Indexed values for LA, PV and LAA anatomy corrected for body size were broadly similar.
Conclusions: In a cohort of individuals matched for AF risk factors, we could find no strong evidence of ethnic differences in LA, PV, and LAA characteristics that may explain a predisposition of Indigenous Australians for atrial arrhythmogenesis. These findings, in conjunction with our previous data showing highly prevalent cardiometabolic risk factors in Indigenous Australians with AF, suggest that it is these conditions that are more likely responsible for the AF substrate in these individuals. Continued efforts should therefore be directed towards risk factor management in an attempt to prevent and minimise the effects of AF in Indigenous Australians.

1. Introduction

Cardiovascular disease remains a leading cause of morbidity in Indigenous populations. In Australia, it is responsible for at least one-third of the gap in life-expectancy between Indigenous and non-Indigenous populations.[1] Much attention has been focussed on the impact of coronary heart disease, stroke, and traditional cardiometabolic risk factors in these populations.[2–4] However, recent data suggest that atrial fibrillation (AF) may be a contributor that has hitherto not been adequately explored.[5] Initial reports demonstrate that Indigenous Australians present with AF at particularly young age.[6,7] As AF is an established cause of stroke, heart failure and death, and an emerging risk factor other conditions relevant to Indigenous health such as chronic kidney disease, it seems very plausible that AF may be in-part contributing to poorer

Abbreviations: AF, Atrial fibrillation; LA, Left atrium; PV, Pulmonary vein; LAA, Left atrial appendage; BMI, Body mass index; BSA, Body surface area.

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outcomes.[8,9] Inadequate access to and receipt of guideline-recommended management, such as anticoagulation therapy, may also heighten the impact of AF in these populations.[10] As a result, an exploration of possible factors associated with the increased burden of AF in Indigenous populations may provide useful mechanistic, preventative, and management insights.

Ethnic disparities in AF burden have been previously described in other populations. For example, studies have consistently reported a greater prevalence of AF in Caucasians compared to those of African or Asian descent. [11,12] An elegant series of investigations have suggested that this is more likely to be explained by a genetic predisposition of Caucasians rather than a differential profile of coexisting risk factors for AF. [13] Furthermore, this genetic tendency may be mediated by variances in cardiac structures such as the left atrium (LA). [14] However, anatomy crucial to atrial arrhythmogenesis has not been previously characterised in Indigenous populations. In the present study, we thus sought to describe LA, pulmonary vein (PV), and left atrial appendage (LAA) anatomy in Indigenous Australians. We compared these anatomical features to a group of non-Indigenous Australians to determine if there was any strong evidence for differences in LA, PV and LAA anatomy that might provide a basis for the greater AF burden seen in Indigenous Australians.

2. Methods

2.1. Study population

We identified patients undergoing 320-row multi-detector computed tomography coronary angiography for evaluation of chest pain at Alice Springs Hospital between 2014 and 2017. Forty individuals were consecutively matched for ethnicity (Indigenous and European Caucasian descent), age, gender, and body mass index (BMI). Individuals with known AF were excluded from this study. Demographic information, ethnicity, anthropometric measurements, cardiovascular comorbidities, and medication use were recorded at the time of scanning and confirmed through manual case record review. All patients provided written informed consent to the procedure, and institutional study approval was obtained from the Central Australian Human Research Ethics Committee.

2.2. Computed tomography

Computed tomography was performed using an Aquilion One 320-row multi-detector computed tomography scanner (Toshiba Medical Systems, Japan). Imaging was triggered manually during the arterial phase and scan parameters were as follows: detector collimation 320 × 0.5 mm; tube current between 300 and 500 mA depending on BMI; tube voltage 100–120 kV; gantry rotation time 270 or 350 ms; and temporal resolution 135 or 175 ms. A 55 ml bolus of 100% iohexol 56.6 g/75 ml (Omnipaque 350) was injected at a rate of 5 ml per second into the antecubital vein, followed by a 20 ml bolus of a 30:70 mixture of contrast medium and saline, followed by a 30 ml bolus of saline. All patients underwent were prospective electrocardiogram gated scans. After image acquisition, raw data was exported, postprocessed, and analysed on a dedicated workstation (Vitrea Fx 6.6.2, Vital Images, USA).

2.3. Image analysis

First, LA anatomy was characterised. Multiplanar reformatting was initially used to assess the LA dimensions in three orthogonal dimensions: anteroposterior, longitudinal, and transverse. Three-dimensional volume rendered reconstructions of the LA were subsequently undertaken. The mitral annulus was taken to be the atrioventricular border, and the mitral annulus was excluded at the point of insertion of the mitral valve leaflets. LA volumes were calculated after exclusion of the PVs at their ostia and the LAA at its base.

Second, PV anatomy was evaluated (Fig. 1). The anatomy of the PVs was initially assessed using three-dimensional volume rendered reconstructions. PV morphology was determined by the presence or absence of a common trunk and/or additional veins. A common trunk was defined when the superior and inferior PV joined greater than 5 mm before entering the LA, resulting in a single atriopulmonary venous junction. An additional PV was defined as a supernumerary vein directly entering the LA. Multiplanar reformatting was subsequently used to align two orthogonal planes parallel to the course of each PV. The third orthogonal plane was oriented perpendicular to the course of each PV, and used to measure the diameter of each PV in the anteroposterior and superoinferior direction. The ratio between the superioinferior and anteroposterior diameter was defined as the eccentricity index to assess the oval shape of each PV ostium. Ostial borders were manually traced to determine areas.

Third, the LAA anatomy was assessed (Figs. 2 and 3). We first used three-dimensional volume rendered reconstructions to characterise LAA morphology. We defined the morphology of the LAA as previously described: "windsock" if the primary structure was one dominant lobe of sufficient length, as "chicken wing" if there was an obvious bend in the proximal to middle part of the dominant lobe, as "cauliflower" if the LAA was of limited length with a distal width exceeding the proximal width, and "cactus" if there was a dominant central lobe with extending secondary lobes. [15,16] The volume of the LAA was calculated after separating the LAA from the LA. Two-dimensional assessment of the LAA included ostial measurements (ostial area, maximum diameter, minimum diameter, eccentricity as assessed by the ratio of the maximum to minimum diameter) and LAA depth (Fig. 2).

2.4. Statistical analysis

Continuous variables are reported as means with standard deviations and categorical variables reported as counts and percentages. Study sample characteristics according to ethnicity were compared using an independent samples *t*-test for continuous variables, and chi-squared or Fishers exact tests for categorical variables respectively, as appropriate. BMI was calculated as weight in kilograms divided by the square of height in metres, and body surface area (BSA) was determined using the Mostellar formula.[17] Indexed values for LA, PV, and LAA dimensions were calculating by correcting for BSA. Post-analysis power and sample size calculations were undertaken using observed means and standard deviations. Statistical tests were performed using Stata 13.0 (Stata Corporation, Texas, USA) and a two-tailed p-value of $p < 0.05$ was considered statistically significant.

3. Results

3.1. Patient characteristics

A total of forty individuals were included in the study population (twenty Indigenous Australians and twenty non-Indigenous Australians). The demographic and clinical characteristics of these individuals are shown in Table 1. The age range of the study population was 30–61 years of age, and 35% were male. Indigenous and non-Indigenous Australians had similar mean age, gender proportions and BMI. However, Indigenous Australians had significantly lower weight ($p = 0.004$) and BSA ($p = 0.007$). There were no significant differences with regards to other comorbidities and

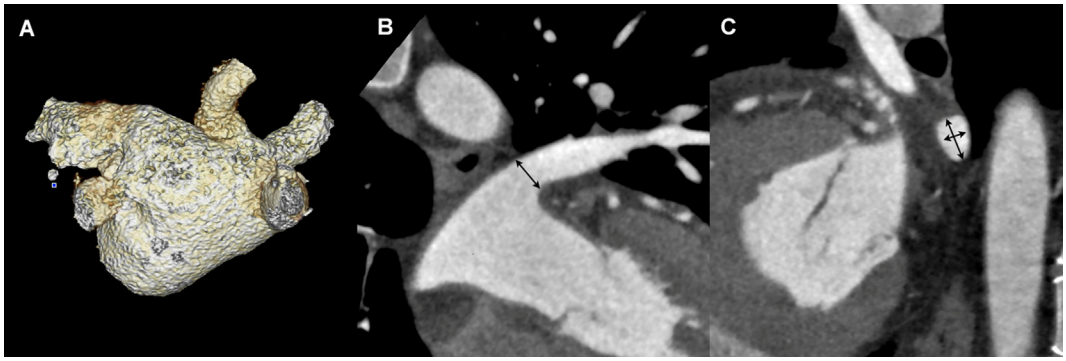

Fig. 1. Assessment of Pulmonary Vein Morphology and Dimensions. Example images showing methods used to assess of pulmonary vein morphology and dimension. (A) Shows three-dimensional volume reconstruction of the left atrium depicting an additional pulmonary vein. (B) Demonstrates measurement of a pulmonary vein diameter in one orthogonal plane. (C) Depicts a plane perpendicular to the vein course used to assess pulmonary vein area.

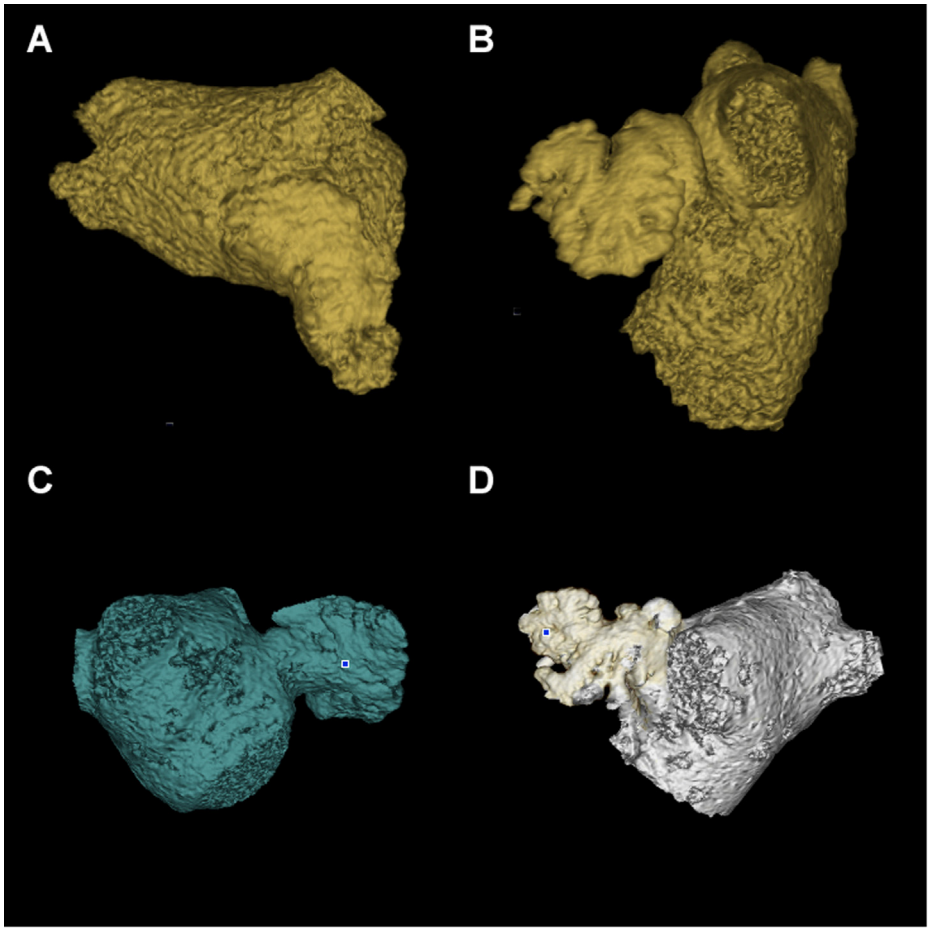

Fig. 2. Characterisation of Left Atrial Appendage Morphology. Example images of various left atrial appendage morphologies: (A) windsock, (B) chicken wing, (C) cauliflower, and (D) cactus. See text for detailed description.

medication use between Indigenous Australians and non-Indigenous Australians.

3.2. Left atrium

LA dimensions were measured in three orthogonal directions: anteroposterior, longitudinal, and transversal. There were no significant differences in these LA diameters between Indigenous and non-Indigenous Australians (Table 2). Similarly, there was no significant difference in LA volumes from three-dimensional reconstructions according to ethnicity (Table 2). Indigenous and non-Indigenous Australians also had similar indexed values for LA volume and LA dimensions corrected for BSA (Supplementary Table).

3.3. Pulmonary veins

A total of 166 PVs were identified for analysis. Gross PV anatomy was first assessed according to the presence or absence of common PV trunks and additional PVs (Fig. 1). A minority of patients exhibited these anatomical variations, with no significant

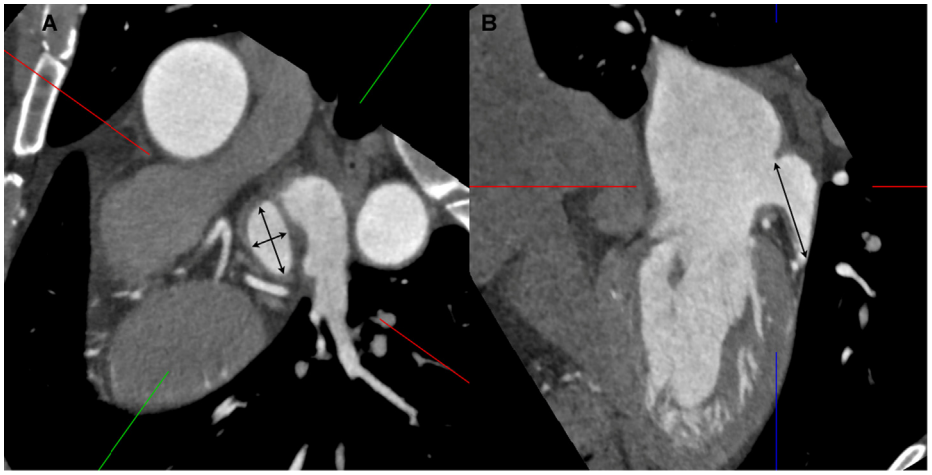

Fig. 3. Measurement of Left Atrial Appendage Dimensions. Example images showing views used to measure LAA dimensions. (A) Shows a plane through the ostium used to characterise LAA ostial area, maximum and minimum dimensions. (B) Demonstrates a plane used to measure LAA depth (B). See text for detailed description.

Table 1
Baseline Characteristics.

	Overall (n = 40)	Indigenous Australians (n = 20)	Non-Indigenous Australians (n = 20)	P Value
Age, y	46.3 ± 8.1	44.5 ± 6.9	48.2 ± 8.9	0.15
Male gender, n (%)	14 (35)	7 (35)	7 (35)	1.00
Height, cm	169.6 ± 10.8	168.0 ± 11.7	169.2 ± 10.1	0.36
Weight, kg	86.5 ± 11.1	81.9 ± 10.8	91.1 ± 9.6	0.004
Body mass index, kg/m^2	30.8 ± 60	29.5 ± 6.5	32.2 ± 5.4	0.17
Body surface area, m^2	2.01 ± 0.14	1.95 ± 0.14	2.07 ± 0.12	0.007
Hypertension, n (%)	19 (48)	8 (40)	11 (55)	0.34
Dyslipidaemia, n (%)	20 (50)	10 (50)	10 (50)	1.00
Type 2 diabetes mellitus, n (%)	11 (28)	6 (30)	5 (25)	0.72
Smoking history, n (%)	13 (33)	4 (20)	9 (45)	0.09
Antihypertensive use, n (%)	12 (30)	7 (35)	5 (25)	0.49
Statin use, n (%)	11 (28)	7 (35)	4 (20)	0.29

differences according to Indigenous status (Table 1). PV dimensions were larger in the superoinferior dimension compared to the anteroposterior dimension (14.7 ± 2.0 vs 13.1 ± 2.0 mm, p < 0.001). The ostia of upper PVs were non-significantly larger than the ostia of lower PVs (192.2 ± 65.3 vs 178.9 ± 82.2 mm, p = 0.48), and the ostia of right-sided PVs significantly larger than the ostia of left-sided PVs (212.0 ± 61.6 vs 145.8 ± 43.8 mm, p < 0.001). Left sided PVs had non-significantly greater eccentricity of their ostia compared to right sided PVs (0.93 ± 0.14 vs 0.99 ± 0.14, p = 0.09); upper and lower PVs had similar ostial eccentricity (0.92 ± 0.18 vs 0.99 ± 0.16, p = 0.15). There were no significant differences in uncorrected PV dimensions or ostial characteristics (area and eccentricity index) between Indigenous and non-Indigenous Australians (Table 2). With the exception of indexed left inferior PV superioinferior diameters, which appeared larger in Indigenous Australians (8.3 ± 1.2 vs 6.9 ± 1.5 mm/m^2, p = 0.008), other comparison of PV dimensions and ostial area corrected for BSA did not show any consistent differences according to ethnicity (Supplementary Table).

3.4. Left atrial appendage

Three-dimensional volume reconstructions were first used to assess LAA morphology in line with previously described types (windsock, chickenwing, cauliflower and cactus; Fig. 2 and Table 1). There were significant overall differences in the proportion of LAA morphological types between Indigenous and non-Indigenous Australians (p = 0.009) that was due to a greater proportion of non chickenwing LAA type in Indigenous Australians (p = 0.025). LAA volumes did not appear to differ according to ethnicity (Table 1). Indigenous Australians exhibited smaller minimum ostial LAA diameters (p = 0.02), such that they had greater ostial eccentricity or oval-shape (p = 0.002; Table 1). There were no significant differences in LAA depth. Comparisons of indexed values corrected for BSA revealed no material differences (Supplementary Table).

4. Discussion

4.1. Major findings

To the best of our knowledge, LA, PV, and LAA anatomy has not been previously characterised in Indigenous populations. We thus sought to study a population of Indigenous and non-Indigenous Australians that were similar in regard to age, gender, and other AF risk factors. Apart from the possible exception of LAA morphology and ostial eccentricity, we found no evidence to suggest significant other differences in LA, PV, and LAA anatomy that may be mediated by ethnicity, as opposed to structural remodelling predisposing to AF from comorbid risk factors. Analyses were similar even after correcting for body size with indexed values. Taken together, the totality of our data supports the likelihood that prevalent risk factors, rather than true ethnic differences, underlie arrhythmogenic substrates predisposing to AF in Indigenous Australians. Continued efforts to reduce the impact of risk factors is thus warranted to minimise the burden of AF in these individuals.

4.2. Racial differences in AF

In recent years, it has been increasingly recognised that AF varies according to ethnicity. Such variation in the incidence of AF has

Table 2
Left Atrial, Pulmonary Vein, and Left Atrial Appendage Dimensions.

	Overall (n = 40)	Indigenous Australians (n = 20)	Non-Indigenous Australians (n = 20)	P Value
Left Atrial				
Volume, mL	65.0 ± 16.3	64.2 ± 15.5	65.9 ± 17.6	0.75
Anteroposterior Diameter, mm	29.3 ± 5.5	28.0 ± 4.5	30.6 ± 6.1	0.13
Longitudinal Diameter, mm	53.4 ± 8.1	54.2 ± 6.3	52.6 ± 9.7	0.55
Transverse Diameter, mm	45.9 ± 7.0	45.7 ± 7.9	46.0 ± 6.2	0.90
Pulmonary Vein				
Additional PVs, no of patients (%)	6 (15)	1 (5)	5 (25)	0.08
Common PV trunk, no of patients (%)	8 (20)	4 (20)	4 (20)	1.00
RSPV Anteroposterior Diameter, mm	15.1 ± 2.8	15.0 ± 2.3	15.2 ± 3.3	0.86
RSPV Superoinferior Diameter, mm	16.1 ± 4.3	15.5 ± 4.3	16.7 ± 4.3	0.45
RSPV Eccentricity Index	0.99 ± 0.22	1.03 ± 0.22	0.95 ± 0.23	0.24
RSPV Ostial Area, mm^2	245.1 ± 102.0	226.4 ± 85.9	253.7 ± 115.8	0.31
RIPV Anteroposterior Diameter, mm	14.0 ± 3.0	13.8 ± 3.5	14.2 ± 2.4	0.74
RIPV Superoinferior Diameter, mm	14.3 ± 3.0	14.4 ± 3.3	14.2 ± 2.8	0.84
RIPV Eccentricity Index	1.05 ± 0.24	1.05 ± 0.25	1.05 ± 0.23	0.95
RIPV Ostial Area, mm^2	178.9 ± 82.2	191.8 ± 94.6	166.0 ± 68.4	0.38
LSPV Anteroposterior Diameter, mm	11.4 ± 3.0	10.7 ± 3.9	12.1 ± 1.4	0.16
LSPV Superoinferior Diameter, mm	13.6 ± 2.5	12.8 ± 2.4	14.3 ± 2.5	0.11
LSPV Eccentricity Index	0.99 ± 0.22	1.03 ± 0.22	0.95 ± 0.23	0.24
LSPV Ostial Area, mm^2	139.3 ± 54.7	127.3 ± 44.0	151.3 ± 62.7	0.22
LIPV Anteroposterior Diameter, mm	11.8 ± 3.0	11.1 ± 2.2	12.5 ± 3.5	0.17
LIPV Superoinferior Diameter, mm	15.2 ± 2.6	15.9 ± 2.4	14.4 ± 2.7	0.12
LIPV Eccentricity Index	1.05 ± 0.25	1.05 ± 0.25	1.05 ± 0.23	0.95
LIPV Ostial Area, mm^2	152.4 ± 44.6	151.8 ± 42.2	153.1 ± 48.3	0.94
Left Atrial Appendage				
Windsock Type, no of patients (%)	4 (10)	4 (20)	0 (0)	0.009
Chickenwing Type, no of patients (%)	17 (43)	5 (25)	12 (60)	
Cauliflower Type, no of patients (%)	17 (43)	11 (55)	6 (30)	
Cactus Type, no of patients (%)	2 (5)	0 (0)	2 (10)	
Volume, mL	8.4 ± 8.7	7.9 ± 4.8	8.8 ± 11.5	0.75
Ostium Minimum Diameter, mm	14.3 ± 3.8	15.6 ± 3.8	12.9 ± 3.0	0.02
Ostium Maximum Diameter, mm	24.1 ± 5.5	23.6 ± 5.4	24.7 ± 5.7	0.54
Ostium Eccentricity Index	1.75 ± 0.40	1.56 ± 0.34	1.94 ± 0.37	0.002
Ostium Area, mm^2	282.5 ± 114.5	295.1 ± 119.3	270.0 ± 111.0	0.49
Depth, mm	32.9 ± 6.8	33.5 ± 8.2	32.3 ± 5.3	0.60

been previously suggested based on epidemiologic data from different geographic regions. [18] Multi-ethnic cohorts with similar diagnostic methods and clinical settings have since reported compelling data to support true ethnic differences. Available studies have mostly analysed individuals of Caucasian, African-American, Asian, and Hispanic descent. [11,12,19] Despite a lower prevalence of risk factors known to heighten the likelihood of AF, Caucasians have been consistently observed to be at paradoxically greater risk. Ancestral analyses suggest that these racial differences in AF may be genetically mediated. In two large multi-ethnic cohorts, an increasing percentage of European ancestry was associated with a greater risk of AF.[13] Other data demonstrate larger left atrial diameters in Caucasians compared to African-Americans, raising the possibility that genes governing cardiac structure may be responsible. [14] This mechanism has strong biologic plausibility given the crucial role of the LA in providing a vulnerable substrate for atrial arrhythmogenesis, in conjunction with triggers from other sources such as the PVs and other adjacent structures. [20–22]

4.3. AF in Indigenous Australians

We have recently reported data suggesting that Indigenous Australians may experience a greater burden of AF. In a large cohort of 204,668 hospitalised individuals in South Australia, there was a significantly higher prevalence of AF in young Indigenous compared to non-Indigenous Australians.[6] These findings were subsequently confirmed in a hospitalised Western Australian cohort. [7] Substantial ethnic disparities in common AF risk factors (such as hypertension, obesity, diabetes, alcohol, and other cardiovascular disease) were observed and are possible explanations for these trends. However, in an echocardiographic sub study, we noted that Indigenous Australians demonstrated greater LA diameters. [6] This finding, in conjunction with the aforementioned data in other ethnic groups, raises the possibility that genetic differences in cardiac structure may be in-part responsible for the greater burden of AF in Indigenous Australians.

4.4. LA, PV, and LAA anatomy in Indigenous Australians

In the present study, we thus sought to comprehensively characterise relevant cardiac structures crucial to atrial arrhythmogenesis in Indigenous Australians. It is well established that the genesis and maintenance of AF requires the presence of both a susceptible myocardial substrate and electrical triggers. [23] The common hallmark of atrial remodelling that underlies the vulnerable AF substrate is LA dilatation. Although our previous data has suggested that anteroposterior LA diameters may be larger in Indigenous Australians, the LA enlarges in a non-uniform fashion; therefore, comprehensive measurements of the LA, and ideally with volumes, is a superior approach for both mechanistic and clinical assessment. [24] Furthermore, dimensions should be corrected for body surface area when such data is available, which is relevant in smaller sized Indigenous Australians. In the present study, we therefore sought to further assess LA characteristics with high spatial resolution computed tomography. However, we could not demonstrate any significant ethnic differences in two-dimensional diameters or three-dimensional LA volumes. Our results were similar even after correcting for body size.

We also determined measurements of the PVs and LAA in Indigenous Australians. The PVs are a crucial source of AF triggers, and differences in PV anatomy have been recognised to affect the

susceptibility to and recurrence of AF [25–27]. With the exception of superioinferior diameters in the left inferior PVs, which was no longer significant after correction for multiple testing ($p = 0.13$), we could again not demonstrate any consistent differences in PV number, morphology, diameters, or ostial characteristics. However, analyses of the LAA did suggest some potential differences. There was a tendency for non "chickenwing" LAA morphology to be more common in Indigenous Australians. Data suggest that individuals with non chickenwing LAA types may be at higher risk of thromboembolism, a finding that may be related to greater number and complexity of trabeculations [16,28]. Theoretically, it is possible that cardioembolism from the LAA might be a contributor to the higher burden of stroke in Indigenous Australians [3,29]. We also observed more eccentric, oval-shaped LAA ostial in Indigenous Australians. These differences might also predispose to electrical triggers from the LAA, which is a well-recognised extra-PV source [30]. However, there did not appear to be any significant discrepancies with regards to LAA volume, ostial area, or depth.

4.5. Implications

Overall, the present results as a whole do not suggest marked ethnic differences in LA or PV anatomy, albeit there may be some subtle differences in LAA characteristics which require confirmation in future studies. The finding of small differences in anteroposterior LA diameter in our previous study may have been related to the use of a single two-dimensional measurement or residual confounding from both measured and unmeasured factors [6]. Furthermore, our results are not adjusted for multiple testing and these isolated significant findings should thus be interpreted with caution. In the current study, our study population was carefully matched for age, gender, and other comorbidities, to avoid the potential confounding effects of these factors on anatomical remodelling. Taken together, these data are more supportive of the theory that Indigenous Australians experience a greater burden of AF due to disparities in cardiometabolic risk factors, and are less consistent with any true ethnic predisposition [31]. The implication of this finding is that an aggressive approach to risk factor management is required to prevent and manage established AF in Indigenous Australians [32,33]. This is important as worsening risk factor trends are likely to translate into a greater prevalence of AF in upcoming years, and these individuals already face considerable barriers in access to, and receipt of, evidenced-based AF care [10]. Our results also provide useful anatomical information for Indigenous and non-Indigenous Australians who undergo relevant invasive procedures, such as AF ablation or left atrial appendage closure. Furthermore, the possibility that LAA differences may predispose to extra-PV triggers could warrant consideration for electrical isolation of the LAA when these individuals undergo AF ablation procedures [30].

4.6. Limitations

Indigenous Australians included in this study reside in Central Australia; given geographical isolation, it is theoretically possible that individuals from other Indigenous communities may exhibit other anatomical differences. Our study population was also limited in size which may have reduced our ability to detect smaller differences in LA, PV, or LAA anatomy. However, power calculations based on our results suggest that many hundreds, if not thousands, of individuals might be required to demonstrate any small potential differences in measured characteristics, and the relevance of such small differences is less certain. In addition, the present study only assessed anatomical differences in LA, PV and LAA characteristics which other studies have suggested may genetically mediate ethnic differences in AF. It may be possible that predisposing electrophysiological abnormalities exist in Indigenous Australians that are not associated with, or have not yet resulted in, structural atrial remodelling. However, detailed electrophysiological and electroanatomic characterisation would require invasive mapping studies, and even patients with lone arrhythmia appear to demonstrate subtle but detectable anatomic remodelling [34,35]. The effect of age, hypertension, and other risk factors on structural remodelling may also become more prominent after many decades; this may be potentially be another explanation for the difference in single-dimension LA diameter seen in our previous study with older adults [24]. Finally, although we could not detect strong evidence to support differences in LA, PV, and LAA characteristics which are crucially involved in the development of AF, there may be other cardiac structural and functional changes predisposing to arrhythmogenesis that we have not assessed in this study.

5. Conclusion

In a cohort of Indigenous and non-Indigenous Australians matched for age, gender and other AF risk factors, we could find no strong evidence to suggest that anatomical differences in LA, PV, and LAA characteristics may represent a genetic predisposition of Indigenous Australians to develop AF. Our data instead support the greater likelihood that highly prevalent risk factors in Indigenous Australians are driving the greater burden of AF in these individuals. Continued efforts should therefore be directed towards risk factor management in an attempt to minimise the effects of AF in Indigenous Australians.

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7. Potential conflicts of interest

Dr Roberts-Thomson reports having served on the advisory board of St. Jude Medical. Dr Sanders reports having served on the advisory board of Medtronic, Abbott, Boston Scientific, Pacemate and CathRx. Dr Sanders reports that the University of Adelaide has received on his behalf lecture and/or consulting fees from Medtronic, Abbott Medical, and Boston Scientific. Dr Sanders reports that the University of Adelaide has received on his behalf research funding from Medtronic, Abbott Medical, Boston Scientific, and MicroPort. Dr. Wong reports that the University of Adelaide has received on his behalf lecture, travel and/or research funding from Abbott, Bayer, Boehringer Ingelheim, Medtronic, Novartis, Servier, and St Jude Medical.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcha.2021.100775.

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