Journal of Interventional Cardiac Electrophysiology (2019) 56:127–135
https://doi.org/10.1007/s10840-018-0398-z

Arrhythmia care in Africa

Demilade Adedinsewo[1] · Oluwatosin Omole[2] · Oludamilola Oluleye[1] · Itse Ajuyah[3] · Fred Kusumoto[4]

Received: 19 March 2018 / Accepted: 4 June 2018 / Published online: 22 June 2018

Abstract
Data on cardiovascular disease, including arrhythmias, in Africa is limited. However, the burden of cardiovascular disease appears to be on the rise. Recent global data suggests an increase in atrial fibrillation rates despite declining rates of rheumatic heart disease. Atrial fibrillation is also associated with increased mortality in Africa. Current management with medical therapy is sub-optimal and ablation procedures, inaccessible. Atrial fibrillation is also an independent risk factor for death in patients with rheumatic heart disease. Sudden cardiac deaths from ventricular arrhythmias are under-recognized and inadequately treated with very high rates out of hospital cardiac arrest due to poor education of the general public on cardiopulmonary resuscitation skills and lack of essential healthcare infrastructure. Use of cardiac devices such as implantable defibrillators and pacemakers is low with significant regional variations and is almost non-existent in sub-Saharan Africa. There is a great unmet need for arrhythmia diagnosis and management in Africa. Governments and healthcare stakeholders need to include cardiovascular disease as a healthcare priority given the rising burden of disease and associated mortality.

Keywords Africa · Arrhythmia · Cardiovascular disease · Cardiac devices

1 Introduction

Africa is the world's second largest continent and accounts for 16% of the world population [1]. The adoption of western culture has led to the development of hypertension, obesity, coronary artery disease, and diabetes, which has contributed to an increased risk of atrial fibrillation (AF) and sudden cardiac death (SCD) [2]. Data on the prevalence and management of arrhythmias in Africa is limited [3–5] and no national registries are available [6]. In addition, guidelines geared toward the African population for the management of cardiovascular disease including cardiac arrhythmias are limited. The South Africa Heart Association subscribes to the guidelines issued by the European Society of Cardiology but also publishes position papers and commentary on specific guidelines for local circumstances [7]. Although multiple international guidelines created in North America and Europe are readily available for review in African countries, studies have not evaluated whether this has been accompanied by provider compliance with the guidelines.

Information on general health indicators in sub-Saharan Africa are sparse and cardiovascular epidemiology data is even more so. There are varying concerns regarding data quality due to poor data collection methods and limited healthcare infrastructure for data gathering, processing, and analysis. Direct epidemiological data are not available and there are no vital registration systems in 42 of 46 countries in sub-Saharan Africa which causes significant difficulty in estimating mortality and burden of disease in this region [2]. The 2010 global burden of disease study provides some insight into cardiovascular disease burden in Africa and showed the leading cardiovascular cause of death and disability in sub-Saharan Africa was stroke [2, 8]. In addition, the largest relative increase in cardiovascular disease burden was in atrial fibrillation with a 91% increase in disability-adjusted life years (DALYs) between 1990 and 2010 [8].

✉ Fred Kusumoto
Kusumoto.Fred@mayo.edu

[1] Department of Cardiovascular Diseases, Mayo Clinic, Jacksonville, FL, USA

[2] University Health System, San Antonio, TX, USA

[3] Division of Cardiology, Department of Medicine, University College Hospital, Ibadan, Nigeria

[4] Division of Cardiovascular Diseases, Electrophysiology and Pacing Service, Mayo Clinic, 4500 San Pablo Ave, Jacksonville, FL 32224, USA

1.1 Supraventricular arrhythmias

AF is the most common sustained arrhythmia in developed countries [9]. The prevalence of AF is reportedly lower in Africa than in the developed world with significant variation across different countries: South Africa 4.6%, Ivory Coast 5.5%, Senegal 5.4%, Kenya 0.7%, Tanzania 0.7% [10], and approximately 3.5% in Nigeria based on two hospital-based retrospective studies [11, 12] (Fig. 1). These low prevalence estimates may be skewed by poor health-seeking behaviors and limited diagnostic equipment in poorly developed health systems. On the other hand, there are reports of a higher prevalence of rheumatic valvular heart disease [10] in Africa compared to the developed world. It is unknown if valvular AF is more common than non-valvular AF in Africa. Results from one study showed approximately 22% of African patients with AF had rheumatic heart disease [13]. Based on the global burden of disease study, the prevalence of rheumatic heart disease in Africa is declining but not AF [8], which suggests an increase in non-valvular AF.

A multi-center observational study of AF patients done in 2010 showed patients from the Middle East and Africa were more likely to be younger and female [3]. The global burden of disease study from 2010 showed AF was more common in men but women with AF had a higher mortality [8]. It is plausible that increasing rates of likely undiagnosed AF may be contributing to the increased burden of stroke-related morbidity and mortality in Africa. Under-recognition of supraventricular arrhythmias subsequently leads to little or no treatment. Thus, the risk of tachycardia-mediated cardiomyopathy is likely increased in the African population with atrial fibrillation and atrial flutter being the most commonly associated arrhythmias [14]. The RELY AF study is a global prospective registry which included patients from 10 African countries who presented to the emergency room with AF between 2008 and 2011 [13]. They showed patients from Africa had the youngest median age (57 years) compared to North America (70 years) or Europe (69 years).

Permanent AF in Africa is also reported to be more common ranging from 40% to as high as 81% compared to paroxysmal AF which ranges from 9 to 40% [9, 10, 13]. The prevalence of heart failure among patients with AF in Africa was estimated to be approximately 64% with more than 60% of these being heart failure with reduced ejection fraction [13].

Anticoagulant and rate-controlling medications are the mainstay therapy for AF management. Although warfarin is readily available and affordable, anticoagulation rates remain poor in Africa [15] as such, it is possible that this may be contributing to the high stroke-related morbidity and mortality in Africa. The RELY AF registry showed approximately 16% of African AF patients were on warfarin and an additional 4% on other vitamin K antagonist, with the mean time in therapeutic range of 32.7% compared to 62.4% in Western Europe and 50.9% in North America [13]. A prospective study done in Cameroon showed only a third of AF patients followed by cardiologist were on oral anticoagulation with a 1-year mortality rate of 30% [9]; however, about 50% of the patients originally enrolled were lost to follow-up. The global rheumatic heart disease registry (REMEDY) which included 12 African countries [16] showed AF to be a significant independent risk factor for mortality in this population with a 40% increase in the risk of death (hazard ratio: 1.4, 95% CI: 1.10–1.78) [17]. Retrospective studies done in Nigeria also identified atrial fibrillation as a precipitating factor for heart failure [18] as well as a co-occurring condition [19]. Medications used for rate or rhythm control were very low among African patients with prior history of AF. Less than a third were treated with aspirin, 21.7% treated with a β-blocker, 34.5% treated with digoxin, 2% treated with verapamil/diltiazem, and only 5.4% treated with anti-arrhythmic medications including amiodarone, flecainide, propafenone, and sotalol [13].

Novel oral anticoagulants (NOACs) are not readily accessible in Africa and its approval for use varies in different countries. Dabigatran was approved for use in Namibia in 2011, and in 2014, rivaroxaban and dabigatran were approved in Kenya [10]. Rivaroxaban and dabigatran (approved in 2013) are also available in South Africa [10, 20]. Rivaroxaban is the only NOAC approved for use in Nigeria whereas in Uganda and Zimbabwe, NOAC therapy was not available [10] as of 2015. However, approvals are likely continuing, so this list may need to be periodically evaluated and updated. Limited current information is available on NOAC availability, prescribing patterns or use in many countries in Africa.

1.2 Ventricular arrhythmia/sudden cardiac death

Sudden cardiac death (SCD) is an unexpected fatal event occurring in an apparently healthy subject usually resulting from cardiac arrhythmias such as ventricular fibrillation [21–23].

SCD occurs in Africa; however, the epidemiology of sudden cardiac arrest (SCA) is unknown [5]. A single study done in Cameroon estimates the burden of SCD (33.6 deaths per 100,000 person-years) to be similar to the incidence reported in developed countries [24]. An accurate estimate of SCD incidence in Africa is limited by the fact that SCD occurs in an unexpected manner and the practical application of the universal definition of SCD may be limited by retrospective analyses of death certificates and poor exclusion of non-cardiac causes of death [25]. As such, the most accurate way to estimate SCD incidence would be a prospective ascertainment of cases rather than a retrospective review of death certificates [25]. About 80% of SCDs are attributed to coronary artery disease (CAD) and autopsies in African countries revealed that SCD attributable to CAD was on the rise [25, 26]. In Nigeria, hypertensive heart disease and myocardial infarction were common causes of SCD [27, 28]. In Ethiopia, the most common cause of SCD was

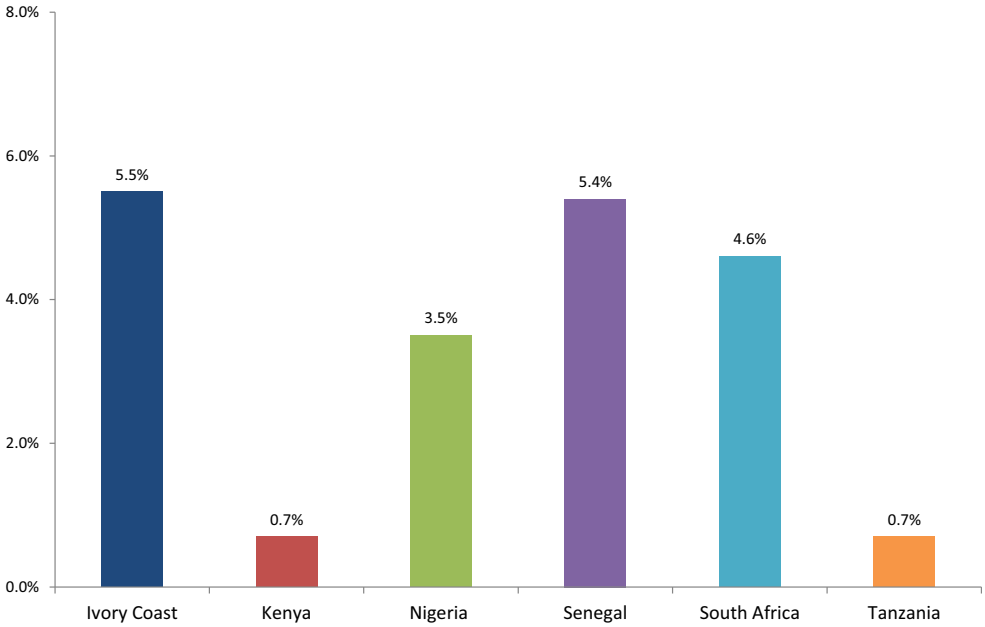

Fig. 1 Prevalence of atrial fibrillation in Africa [10–12], by country

CAD as noted on autopsy [29]. Ventricular arrhythmias in patients with CAD typically occur as a result of acute coronary syndrome (ACS) or re-entry from previous myocardial scarring [25, 30, 31]. Other causes of ventricular arrhythmia, especially in the younger African population, include long QT syndrome, Brugada syndrome, arrhythmogenic right ventricular cardiomyopathy (ARVC), and hypertrophic cardiomyopathy [25, 30]. In Tunisia, 24 patients with Brugada syndrome were followed for 26 months; 11 patients had a family history of SCD, an electrophysiological study induced ventricular fibrillation in six patients, and an implantable cardioverter defibrillator (ICD) was required in 14 patients [24]. ARVC was diagnosed in 50 patients in South Africa over a 5-year period from 2004 to 2009 based on referral by their physicians with the mean age at symptom onset and male predominance similar to those reported in other studies [32]. In addition, a history of syncope and sustained ventricular tachycardia were strongly associated with mortality in patients without an ICD [32]. Long QT syndrome and Lenegre's disease have been described in Africa, although reports from South Africa suggest the genetic forms of long QT syndrome to be more prevalent among whites and absent in blacks [33].

Time is of paramount importance in patients who suffer SCA. Prompt defibrillation is required in SCA patients since survival decreases by 3–4% without immediate cardiopulmonary resuscitation (CPR) and by 7–10% without any CPR at all [34]. Ninety-five percent of patients die after 10 min or longer without defibrillation [34]. Automated external defibrillators (AED) are portable devices that analyze cardiac rhythm, deliver electrical shock required for ventricular tachycardia or fibrillation, and can be operated by an amateur person [30, 35, 36]. The implementation of basic life support (BLS) and advanced cardiac life support (ACLS) in Africa is rare [37]. Bonny et al. reviewed all deaths in two health areas in Douala, Cameroon, and found an age-standardized SCD rate of 33.6 per 100,000 person-years, 88.9% were witnessed cardiac arrests, but only 3.7% had CPR attempted [24]. In Nigeria, multiple small surveys demonstrated that a majority of healthcare workers including physicians, nurses, and medical students did not have adequate BLS/ACLS training and could not operate an AED [38–41]. Although AEDs are available in South Africa, its use is still limited due to the cost of a large-scale roll out and a focus on primary healthcare needs rather than the emergency care needs of the community [42]. Veronese et al. also described poor CPR competency among emergency medical service (EMS) personnel in South Africa [43].

ICD, cardiac resynchronization therapy defibrillator (CRT-D), and wearable cardioverter defibrillator (WCD) are devices recommended for the prevention of SCD provided expected survival is greater than 1 year [44]. In sub-Saharan Africa, visiting specialists help with implanting ICD or CRT devices; however, implantation rates are still very low. South Africa and Kenya are the only countries in sub-Saharan Africa who appear to be self-sufficient with implanting devices while Tunisia has the highest ICD implantation rate in Africa with 12.8 implants per million population [6]. Mauritius, Tunisia, and South Africa had the highest rate of CRT device implantation.

1.3 Bradyarrhythmia

The incidence of bradycardia in Africa is unknown. Permanent pacemakers are implanted primarily for

symptomatic bradycardia, Mobitz type II atrioventricular block, complete heart blocks, and heart failure management (CRT-P) [45]. The Pan-African Society of Cardiology (PASCAR) collected data from 31 African countries from 2011 to 2016 on the use of cardiac implantable electronic devices and catheter ablation procedures [6]. At least, 30% of African countries had limited access to pacemaker insertion and eight of the 31 countries surveyed (26%) did not have access to pacemaker implantation [6]. In South Africa, majority of patients received pacemakers due to complete heart block from degeneration of conduction pathways, post myocardial infarction, and post valve replacement [46]. Mauritius and Tunisia had the highest number of pacemaker implantation centers per million population (~6–7 centers) while all other African countries surveyed had ≤ 1 center per million population [6] (Fig. 2). Dual-chamber pacing is rare but available in South Africa and Ghana. It appears single-chamber pacing may be preferred given lower associated cost and expertise required for placement [6]. A single-site study in Nigeria reports the establishment of pacemaker implantation services in 2008 with only 51 implants done over a 4-year period from 2008 to 2012 [47]. Senegal had an average of 30 pacemaker implants a year over a 3-year study period, mostly for complete heart block and also used more recycled pacemakers [48].

2 Challenges to arrhythmia management in Africa

2.1 Healthcare resource challenges

One of the biggest challenges to managing arrhythmias in Africa is diagnosing it. The appropriate management of arrhythmias in Africa has been hampered by inadequate investments in health systems that are capable of diagnosing and treating arrhythmias. According to the WHO, the current health expenditure in 2015 as a percentage of gross domestic product (GDP) in South Sudan was 3%, Nigeria 4%, and South Africa 8%. This is compared to 10% in the UK and 17% in the USA [49].

Additionally, many African countries have a high burden of infectious diseases to which majority of resources are allocated. Consequently, non-communicable chronic diseases such as cardiovascular disease are not often considered public health priorities. For example, the primary healthcare center is the closest point of contact to healthcare for millions of people who live in rural and semi-urban areas. Many primary health centers however do not have EKG machines to diagnose arrhythmias and these cases are missed and not referred to tertiary centers [50]. For cases referred to tertiary centers, many of these also do not offer device therapies such as cardiac pacemakers, defibrillators, or cardiac resynchronization therapy (CRT) devices due to high cost of device and lack of trained physicians (electrophysiologists) to implant them [51]. The estimated cost of a pacemaker generator and device leads ranges from US$3300 to US$4000 while an ICD generator with device leads costs between US$30,000 and US$50,000 [52].

The inadequacy of other healthcare resources such as anticoagulants, oral and intravenous anti-arrhythmic medications, and other supplies also contributes to the limited management of arrhythmias [53].

2.2 Health system challenges

In the past few years, there has been a strong drive to improve the health systems in many African countries and reduce the focus on single disease. Although the relative burden of communicable diseases such as HIV/AIDS and malaria has declined, it still remains one of the top drivers of health loss in most countries in sub-Saharan Africa. The disease burden from non-communicable diseases, particularly stroke, has increased in the region among the upper- and middle-income countries [54]. Specifically in sub-Saharan Africa, the burden of stroke, ischemic heart disease, and diabetes has increased between 1990 and 2010 by 31, 37, and 88% respectively while the burden of diarrheal diseases and lower respiratory infections have decreased by 34 and 22% respectively (Fig. 3) [54].

While some progress has been made in strengthening health systems, a lot more still has to be done. For example, many countries need to strengthen infrastructure and networks that make the health systems function smoothly. Investments need to be made so that good roads, electricity, constant water supply, and emergency care services are functional and accessible to all. Additionally, healthcare access needs to be improved through the development and expansion of national health insurance programs. In Nigeria, many patients typically have to pay out of pocket for healthcare, which has catastrophic economic and financial implications for families [55–57]. Other African countries face the same challenges with healthcare financing. A comparative study of five African countries (Ethiopia, Ghana, Kenya, Rwanda, and Tanzania) showed that although these countries have introduced social health insurance programs, many of their poor citizens are still not covered by these health insurances or health services are not within reach [58]. There is a growing momentum for universal healthcare coverage and governments must create an enabling environment as well as policy incentives to ensure that all citizens have access to health insurance.

2.3 Manpower challenges

As the burden of cardiovascular diseases continues to rise in Africa, the shortage of trained cardiologists and

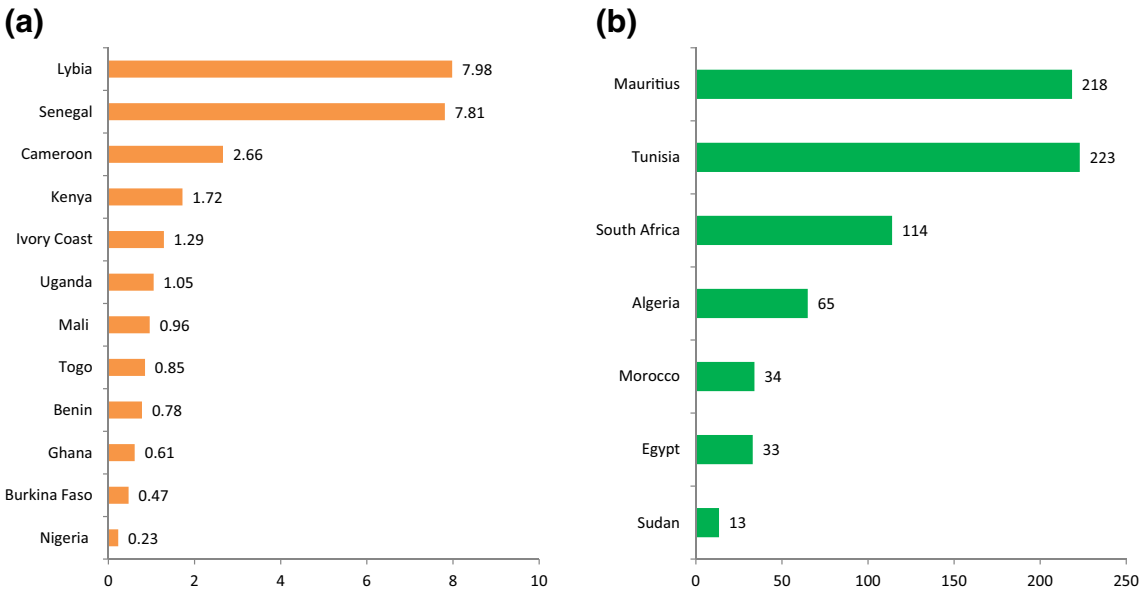

Fig. 2 **a**, **b** Pacemaker implantation rates per million population in Africa by country, 2013 estimates [6]. **a** shows countries with very low implantation rates and **b** shows African countries with higher implantation rates

electrophysiologists remains an important challenge to the management of cardiovascular conditions in general and arrhythmias specifically. Additionally, there are very few thoracic and cardiac surgeons. Estimates from 2016 suggest that there are approximately 200 cardiologists for 52 million South Africans [51] and 80 cardiologists in Senegal with a population of 14.2million [59]. In the USA, it is estimated that there were approximately 30,000 cardiologists in 2013 for a population of 320 million [60, 61]. The limited manpower is also due to inadequate advanced post graduate cardiac training in electrophysiology in Africa [6]. For example, in South Africa, there are only eight programs with the ability to train a cardiologist. General cardiology training is usually over a 3-year period after completing 4 years of training as a general

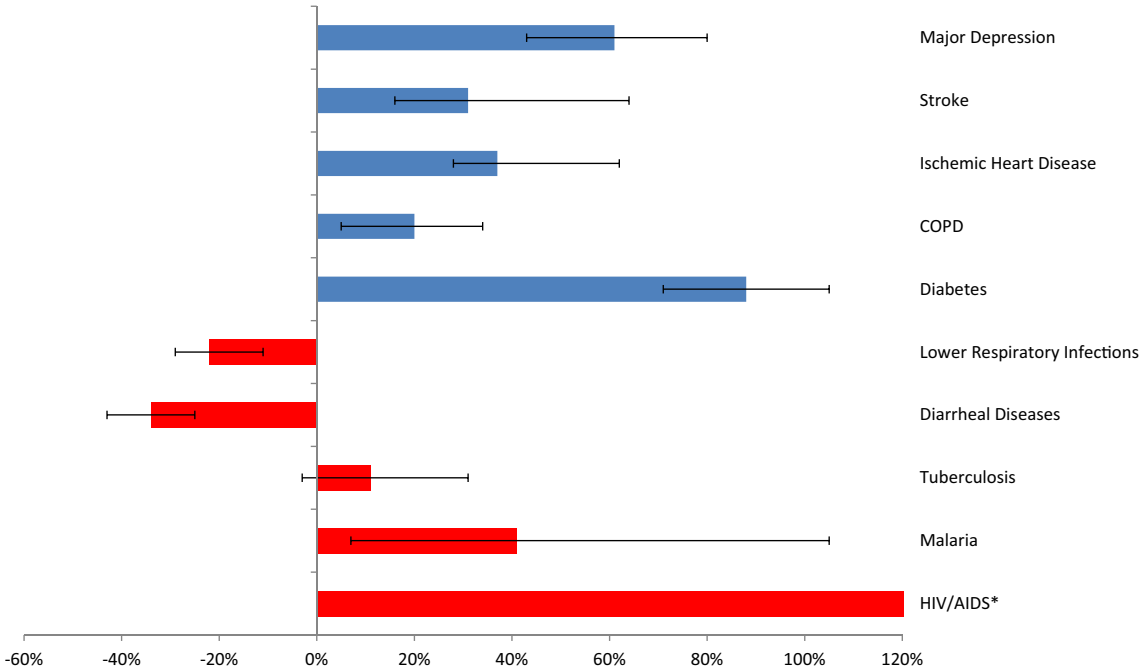

Fig. 3 Change in disease burden for 10 common diseases between 1990 and 2010, measured in disability adjusted life years (DALY) [54]. Bars to the right of the vertical line show the proportion by which DALYs have increased while bars on the left showed the proportion by which DALYs have decreased over the 20-year period. Uncertainty intervals (UI) displayed with error bars. *Proportion increase much greater than shown in figure—DALY for HIV increased by 328% (95% UI: 274–393). Data obtained from the global burden of disease study, sub-Saharan Africa region

medicine physician [51]. Currently, EP training is only offered at the University of Cape Town, Groote Schuur Hospital [62, 63], in South Africa (first fellow appointed in 2010) and there are only 13 registered EP physicians in the country [51]. The West African College of Physicians (WACP) includes eight chapter countries—Gambia, Ghana, Ivory Coast, Liberia, Nigeria, the Republic of Benin, Senegal, and Sierra Leone [64]. WACP's residency training curriculum currently requires an initial 24-month training in internal medicine and a subsequent 36-month focused subspecialty training fellowship in general cardiology. Although general cardiology fellows are encouraged to gain exposure to advanced cardiology techniques, there are no advanced fellowship training programs in electrophysiology, interventional cardiology, or advanced heart failure at this time. Consequently, there are concerns that implementation of standard protocol and guideline-directed medical therapy for arrhythmia management are likely not followed given the expertise is limited. In the USA, the American Board of Internal Medicine (ABIM) subspecialty board on cardiovascular diseases requires 3 years of fellowship training in general cardiology following completion of a 3-year residency training in internal medicine. Additional years of training is required for advanced specialty fellowships in clinical cardiac electrophysiology, interventional cardiology, advanced heart failure and transplant cardiology, and adult congenital heart disease [65]. Optional training in pacemaker implantation is available during the 3 years of general cardiology training if 6 months is dedicated to acquiring the knowledge and skills required. However, an additional minimum 12 months of training is required after the standard 3-year general cardiology training to obtain privileges to implant cardiac implantable electrical devices (CIED) including ICD and biventricular devices [66].

3 Proposed solutions

A robust response to the complex challenges of arrhythmia management in Africa requires a strategic framework for action. The first step is for countries to realize the magnitude of the challenges and articulate a cohesive and well-thought-out response. Increasing healthcare spending will help but it is not the "cure-all." Some key reforms in domestic healthcare financing can help. In the near term, efforts can be made to raise money through innovative financing mechanisms such as luxury tax, tobacco taxes, airline ticket taxes, and lotteries [67]. Country budgets and funding allocations have to be properly accounted for and spent on the right priorities which will ultimately improve the health system. The PASCAR report demonstrated that indicators of good governance, such as high GDP per capita, life expectancy at birth, health expenditure as percentage of GDP or per capita, and human development index, were directly related to better cardiac arrhythmia services [6].

An enabling environment also has to be created to recruit and train cardiologists and electrophysiologists. The government must provide the right incentives to encourage young physicians to train in the field of cardiology such as improved pay, opportunities to train overseas, and the provision of necessary healthcare infrastructure and diagnostic equipment. The lack of international standard fellowship programs in African countries has been identified as one of the main drivers of poor interventional cardiac arrhythmia care [6]. Physician expertise can also be improved by creating training partnerships within Africa, where North African countries with better arrhythmia care and management can provide training opportunities for physicians in sub-Saharan Africa. To address training deficiencies, a 6-month PASCAR fellowship in cardiac pacing was recently established in South Africa and their first fellow started in March 2016 [51]. In addition, the University of Cape Town also recently started the first interventional cardiology training program in sub-Saharan Africa as a 2-year master's degree with 1 year of clinical training and 1 year of practical training and the first candidate began training in March 2017 [68]. The PASCAR fellowship is also used to train physicians and technologists in other African countries such as Kenya and Sierra Leone. The long-term goal of this fellowship is to provide the needed skills for device implantation in underserved African countries [52]. In addition, the team is looking at alleviating CIED cost by encouraging device donation for reuse if they have sufficient battery life [52].

3.1 Device therapies, EP procedures, and diagnostic tools

The high cost of devices such as pacemakers and ICD for arrhythmia management has been reported to be a major limitation in providing these therapies to patients in low-income countries like Africa [6, 69]. Diagnosing arrhythmias also pose a challenge in resource-poor areas of Africa where basic diagnostic tools such as electrocardiograms are scarce in multiple healthcare settings ranging from outpatient clinics to inpatient settings [70]. As such, patients with treatable arrhythmias are likely missed, develop complications or experience sudden death. Ablation procedures are scarce to non-existent in many regions in Africa with no EP center in sub-Saharan Africa (with the exception of South Africa and Senegal) [6]. Although South Africa has EP services, they still depend mostly on device representatives for troubleshooting and device interrogation [51]. Novel portable cardiac monitoring devices available directly to consumers (such as Fitbits, Apple Watch, and Kardia mobile) may present a unique opportunity for improved diagnosis in Africa but are they well equipped to manage these patients who were previously unidentified?

Governments, device manufacturers, non-profit non-governmental organizations, physician associations, and other

stakeholders all have a role to play in improving access to arrhythmia care in Africa and the PASCAR report provides a call to action and identifies an urgent need for expansion of EP services in Africa.

4 Conclusion

Arrhythmias potentially affect millions of people in Africa but remain undetected and untreated. There is no gainsaying that the proper detection and management of arrhythmias will reduce arrhythmia-associated morbidities such as stroke and heart failure. It will also reduce sudden cardiac death. While the size and complexity of arrhythmia in Africa cannot be captured easily, the overarching message of this article is that further research and analysis are needed with regard to the epidemiology and management of cardiovascular diseases including arrhythmias in Africa. Additionally, the significant gaps in manpower, health systems, and healthcare resources must be bridged so that key global recommendations and guidelines regarding arrhythmias can be implemented. A unique responsibility lies with national governments as efforts are made to address the challenges discussed above. We hope that this article will inspire scholars, practitioners, and governments to action on cardiovascular disease in Africa.

References

1. United Nations, Population. United Nations. http://www.un.org/en/sections/issues-depth/population/. Accessed Feb 22 2018.
2. Mensah GA, Roth GA, Sampson UK, Moran AE, Feigin VL, Forouzanfar MH, et al. Mortality from cardiovascular diseases in sub-Saharan Africa, 1990–2013: a systematic analysis of data from the Global Burden of Disease Study 2013. Cardiovasc J Afr. 2015;26(2 Suppl 1):S6–10. https://doi.org/10.5830/cvja-2015-036.
3. Gamra H, Murin J, Chiang CE, Naditch-Brule L, Brette S, Steg PG. Use of antithrombotics in atrial fibrillation in Africa, Europe, Asia and South America: insights from the International RealiseAF Survey. Arch Cardiovasc Dis. 2014;107(2):77–87. https://doi.org/10.1016/j.acvd.2014.01.001.
4. Rahman F, Kwan GF, Benjamin EJ. Global epidemiology of atrial fibrillation. Nat Rev Cardiol. 2014;11(11):639–54. https://doi.org/10.1038/nrcardio.2014.118.
5. Chin A. Sudden cardiac death in Africa. Cardiovascular journal of Africa. 2014;25(4):151–2.
6. Bonny A, Ngantcha M, Jeilan M, Okello E, Kaviraj B, Talle MA, et al. Statistics on the use of cardiac electronic devices and interventional electrophysiological procedures in Africa from 2011 to 2016: report of the Pan African Society of Cardiology (PASCAR) Cardiac Arrhythmias and Pacing Task Forces. Europace. 2017; https://doi.org/10.1093/europace/eux353.
7. Guidelines: SA Heart. https://www.saheart.org/cms-home/category/17. Accessed June 1 2018.
8. Moran A, Forouzanfar M, Sampson U, Chugh S, Feigin V, Mensah G. The epidemiology of cardiovascular diseases in sub-Saharan Africa: the Global Burden of Diseases, Injuries and Risk Factors 2010 Study. Prog Cardiovasc Dis. 2013;56(3):234–9. https://doi.org/10.1016/j.pcad.2013.09.019.
9. Ntep-Gweth M, Zimmermann M, Meiltz A, Kingue S, Ndobo P, Urban P, et al. Atrial fibrillation in Africa: clinical characteristics, prognosis, and adherence to guidelines in Cameroon. Europace. 2010;12(4):482–7. https://doi.org/10.1093/europace/euq006.
10. Stambler BS, Ngunga LM. Atrial fibrillation in sub-Saharan Africa: epidemiology, unmet needs, and treatment options. Int J Gen Med. 2015;8:231–42. https://doi.org/10.2147/ijgm.s84537.
11. Anisiuba B, Ejim E, Onwubere B, Ikeh V, Ike S. Atrial fibrillation cases seen at the University of Nigeria Teaching Hospital, Enugu. Int J Med Health Dev. 2005;10(2):102–6.
12. Ejim E, Ike S, Anisiuba B, Essien I, Onwubere B, Ikeh V. Cardiac arrhythmias in recently diagnosed hypertensive patients at first presentation an electrocardiographic-based study. Niger J Med. 2012;21(1):6–10.
13. Oldgren J, Healey JS, Ezekowitz M, Commerford P, Avezum A, Pais P, et al. Variations in cause and management of atrial fibrillation in a prospective registry of 15,400 emergency department patients in 46 countries: the RE-LY Atrial Fibrillation Registry. Circulation. 2014;129(15):1568–76. https://doi.org/10.1161/circulationaha.113.005451.
14. Chin A, Badri M, Ntusi NB, Okreglicki A. The clinical, electrocardiographic and echocardiographic characteristics and long-term outcome of patients with tachycardia-induced cardiomyopathy. Cardiovascular journal of Africa. 2012;23(3):136–42. https://doi.org/10.5830/cvja-2011-019.
15. Morillo CA, Banerjee A, Perel P, Wood D, Jouven X. Atrial fibrillation: the current epidemic. J Geriatr Cardiol. 2017;14(3):195–203. https://doi.org/10.11909/j.issn.1671-5411.2017.03.011.
16. Karthikeyan G, Zuhlke L, Engel M, Rangarajan S, Yusuf S, Teo K, et al. Rationale and design of a global rheumatic heart disease registry: the REMEDY study. Am Heart J. 2012;163(4):535–40.e1. https://doi.org/10.1016/j.ahj.2012.01.003.
17. Zuhlke L, Karthikeyan G, Engel ME, Rangarajan S, Mackie P, Cupido-Katya Mauff B, et al. Clinical outcomes in 3343 children and adults with rheumatic heart disease from 14 low- and middle-income countries: two-year follow-up of the global rheumatic heart disease registry (the REMEDY study). Circulation. 2016;134(19):1456–66. https://doi.org/10.1161/circulationaha.116.024769.
18. Ojji DB, Alfa J, Ajayi SO, Mamven MH, Falase AO. Pattern of heart failure in Abuja, Nigeria: an echocardiographic study. Cardiovasc J Afr. 2009;20(6):349–52.
19. Ogah OS, Sliwa K, Akinyemi JO, Falase AO, Stewart S. Hypertensive heart failure in Nigerian Africans: insights from the Abeokuta Heart Failure Registry. J Clin Hypertens (Greenwich, Conn). 2015;17(4):263–72. https://doi.org/10.1111/jch.12496.
20. Bergh M, Marais CA, Miller-Janson H, Salie F, Stander MP. Economic appraisal of dabigatran as first-line therapy for stroke prevention in atrial fibrillation. S Afr Med J= Suid-Afrikaanse tydskrif vir geneeskunde. 2013;103(4):241–5. https://doi.org/10.7196/samj.6471.
21. Basso C, Corrado D, Thiene G. Cardiovascular causes of sudden death in young individuals including athletes. Cardiol Rev. 1999;7(3):127–35.
22. Goldstein S. The necessity of a uniform definition of sudden coronary death: witnessed death within 1 hour of the onset of acute symptoms. Am Heart J. 1982;103(1):156–9.
23. Zipes DP, Camm AJ, Borggrefe M, Buxton AE, Chaitman B, Fromer M, et al. ACC/AHA/ESC 2006 guidelines for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death: a report of the American College of Cardiology/American Heart Association Task Force and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Develop Guidelines for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden

Cardiac Death). J Am Coll Cardiol. 2006;48(5):e247–346. https://doi.org/10.1016/j.jacc.2006.07.010.
24. Bonny A, Tibazarwa K, Mbouh S, Wa J, Fonga R, Saka C, et al. Epidemiology of sudden cardiac death in Cameroon: the first population-based cohort survey in sub-Saharan Africa. Int J Epidemiol. 2017;46(4):1230–8. https://doi.org/10.1093/ije/dyx043.
25. Vedanthan R, Fuster V, Fischer A. Sudden cardiac death in low- and middle-income countries. Glob Heart. 2012;7(4):353–60. https://doi.org/10.1016/j.gheart.2012.10.002.
26. Gorgels AP, Gijsbers C, de Vreede-Swagemakers J, Lousberg A, Wellens HJ. Out-of-hospital cardiac arrest—the relevance of heart failure. The Maastricht Circulatory Arrest Registry. Eur Heart J. 2003;24(13):1204–9.
27. Rotimi O, Fatusi AO, Odesanmi WO. Sudden cardiac death in Nigerians—the Ile-Ife experience. West Afr J Med. 2004;23(1):27–31.
28. Akinwusi PO, Komolafe AO, Olayemi OO, Adeomi AA. Pattern of sudden death at Ladoke Akintola University of Technology Teaching Hospital, Osogbo, South West Nigeria. Vasc Health Risk Manag. 2013;9:333–9. https://doi.org/10.2147/vhrm.s44923.
29. Schneider J, Bezabih K. Causes of sudden death in Addis Ababa, Ethiopia. Ethiop Med J. 2001;39(4):323–40.
30. Adabag AS, Luepker RV, Roger VL, Gersh BJ. Sudden cardiac death: epidemiology and risk factors. Nat Rev Cardiol. 2010;7(4):216–25. https://doi.org/10.1038/nrcardio.2010.3.
31. Bunch TJ, Hohnloser SH, Gersh BJ. Mechanisms of sudden cardiac death in myocardial infarction survivors: insights from the randomized trials of implantable cardioverter-defibrillators. Circulation. 2007;115(18):2451–7. https://doi.org/10.1161/circulationaha.106.683235.
32. Watkins DA, Hendricks N, Shaboodien G, Mbele M, Parker M, Vezi BZ, et al. Clinical features, survival experience, and profile of plakophylin-2 gene mutations in participants of the arrhythmogenic right ventricular cardiomyopathy registry of South Africa. Heart Rhythm. 2009;6(11 Suppl):S10–7. https://doi.org/10.1016/j.hrthm.2009.08.018.
33. Falase AO, Ogah OS. Cardiomyopathies and myocardial disorders in Africa: present status and the way forward. Cardiovasc J Afr. 2012;23(10):552–62. https://doi.org/10.5830/cvja-2012-046.
34. Hazinski MF, Idris AH, Kerber RE, Epstein A, Atkins D, Tang W, et al. Lay rescuer automated external defibrillator ("public access defibrillation") programs: lessons learned from an international multicenter trial: advisory statement from the American Heart Association Emergency Cardiovascular Committee; the Council on Cardiopulmonary, Perioperative, and Critical Care; and the Council on Clinical Cardiology. Circulation. 2005;111(24):3336–40. https://doi.org/10.1161/circulationaha.105.165674.
35. Gundry JW, Comess KA, DeRook FA, Jorgenson D, Bardy GH. Comparison of naive sixth-grade children with trained professionals in the use of an automated external defibrillator. Circulation. 1999;100(16):1703–7.
36. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. N Engl J Med. 2002;347(16):1242–7. https://doi.org/10.1056/NEJMoa020932.
37. Bonny A, Amougou SN, Noah Noah D, Mbenoun ML, Karaye K. Sudden cardiac death in low-resource settings: lessons from a resuscitated cardiac arrest. Cardiovasc J Afr. 2015;26(2):91–5. https://doi.org/10.5830/cvja-2015-020.
38. Olajumoke TO, Afolayan JM, Raji SA, Adekunle MA. Cardiopulmonary resuscitation—knowledge, attitude & practices in Osun State, Nigeria. J West Afr Coll Surg. 2012;2(2):23–32.
39. Sadoh W, Osariogiagbon W. Knowledge and practice of cardiopulmonary resuscitation amongst doctors and nurses in Benin city, Nigeria. Nigerian Hospital Practice. 2009;3(1–2). https://doi.org/10.4314/nhp.v3i1-2.45616.
40. Solagberu B. Knowledge and practice of cardiopulmonary resuscitation among Nigerian doctors. Niger J Surg Res. 2002;4(1):12–21.
41. Okonta KE, Okoh BA. Theoretical knowledge of cardiopulmonary resuscitation among clinical medical students in the University of Port Harcourt, Nigeria. Afr J Med Health Sci. 2015;14(1):42.
42. Campbell C, Campbell R. Resuscitation and transport by emergency care workers: resuscitation update. SAJAA. 2010;16(1):135–7.
43. Veronese J-P, Wallis L, Allgaier R, Botha R. Cardiopulmonary resuscitation by Emergency Medical Services in South Africa: barriers to achieving high quality performance. Afr J Emerg Med. 2018;8(1):6–11. https://doi.org/10.1016/j.afjem.2017.08.005.
44. Al-Khatib SM, Stevenson WG, Ackerman MJ, Bryant WJ, Callans DJ, Curtis AB, et al. 2017 AHA/ACC/HRS guideline for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol. 2017; https://doi.org/10.1016/j.jacc.2017.10.053.
45. Epstein AE, DiMarco JP, Ellenbogen KA, Estes NA 3rd, Freedman RA, Gettes LS, et al. 2012 ACCF/AHA/HRS focused update incorporated into the ACCF/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol. 2013;61(3):e6–75. https://doi.org/10.1016/j.jacc.2012.11.007.
46. Dos Santos B, LA A, NE T. Permanent cardiac pacing in South African blacks. S Afr Med J. 1982;61(25):947–9.
47. Falase B, Sanusi M, Johnson A, Akinrinlola F, Ajayi R, Oke D. Analysis of a five year experience of permanent pacemaker implantation at a Nigerian teaching hospital: need for a national database. Pan Afr Med J. 2013;16:16. https://doi.org/10.11604/pamj.2013.16.16.2644.
48. Thiam M, Fall PD, Gning SB, Ott D, Gueye PM, Wade B, et al. Cardiac pacing in West Africa: feasibility, problems, and perspectives. Ann Cardiol Angeiol. 2003;52(4):212–4.
49. World Health Organization. Global Health Expenditure Database. http://apps.who.int/nha/database/ViewData/Indicators/en. Accessed February 24 2018.
50. Bringing 12-lead ECG to Rural Africa. Enabling Diagnosis & Treatment of NCDs in Developing Countries. Levmed. https://www.levmed.net/single-post/2017/07/23/LevMed-Bringing-12-lead-ECG-to-Rural-Africa. Accessed February 24 2018.
51. Sliwa K, Zuhlke L, Kleinloog R, Doubell A, Ebrahim I, Essop M, et al. Cardiology-cardiothoracic subspeciality training in South Africa: a position paper of the South Africa Heart Association. Cardiovasc J Afr. 2016;27(3):188–93. https://doi.org/10.5830/cvja-2016-063.
52. Sani MU, Mayosi BM. The pacemaker and ICD reuse programme of the Pan-African Society of Cardiology. Heart. 2017;103(23):1844–5. https://doi.org/10.1136/heartjnl-2017-311462.
53. Oyekale AS. Assessment of primary health care facilities' service readiness in Nigeria. BMC Health Serv Res. 2017;17(1):172. https://doi.org/10.1186/s12913-017-2112-8.
54. The global burden of disease: generating evidence, guiding policy - Sub-Saharan Africa Regional Edition Human Development Network; The World Bank; Institute for Health Metrics and Evaluation; University of Washington. 2013. http://www.healthdata.org/sites/default/files/files/data_for_download/2013/WorldBank_SubSaharanAfrica/IHME_GBD_WorldBank_SubSaharanAfrica_FullReport.pdf.
55. Amakom U, Ezenekwe UR. Implications of households catastrophic out of pocket (OOP) healthcare spending in Nigeria. J Res Econ Int Finance. 2012;1(5):136–40.
56. Aregbeshola BS. Out-of-pocket payments in Nigeria. Lancet. 2016;387(10037):2506.

57. Onah MN, Govender V. Out-of-pocket payments, health care access and utilisation in south-eastern Nigeria: a gender perspective. PLoS One. 2014;9(4):e93887. https://doi.org/10.1371/journal.pone.0093887.
58. Fenny AP, Yates R, Thompson R. Social health insurance schemes in Africa leave out the poor. Int Health. 2018;10(1):1–3. https://doi.org/10.1093/inthealth/ihx046.
59. Do SA, Nigeria have fewer cardiologists for their populations than Senegal? https://africacheck.org/reports/sa-nigeria-fewer-cardiologists-populations-senegal/. Accessed February 24 2018.
60. Market Profile of U.S. Cardiologists-OneKey Market Insight Report. http://blog.a-b-c.com/wp-content/uploads/2013/07/Market-Profile-of-U.S.-Cardiologists.pdf. Accessed February 24 2018.
61. Number of active physicians in the U.S. in 2017, by specialty area. https://www.statista.com/statistics/209424/us-number-of-active-physicians-by-specialty-area/. Accessed February 25 2018.
62. Millar RS. Peer review and accreditation in cardiac electrophysiology: commentary. SA Heart. 2008;5(4):178–80.
63. Heart specialist awarded prestigious new fellowship. 2010. https://www.news.uct.ac.za/article/-2010-12-13-heart-specialist-awarded-prestigious-new-fellowship. Accessed June 1 2018.
64. West African College of Physicians. https://wac-physicians.org/pages/about-us.php. Accessed March 4 2018.
65. Halperin JL, Williams ES, Fuster V. COCATS 4 introduction. J Am Coll Cardiol. 2015;65(17):1724–33. https://doi.org/10.1016/j.jacc.2015.03.020.
66. Calkins H, Awtry EH, Bunch TJ, Kaul S, Miller JM, Tedrow UB. COCATS 4 task force 11: training in arrhythmia diagnosis and management, cardiac pacing, and electrophysiology. J Am Coll Cardiol. 2015;65(17):1854–65. https://doi.org/10.1016/j.jacc.2015.03.029.
67. Innovative financing for development. http://www.un.org/esa/ffd/documents/InnovativeFinForDev.pdf. Accessed February 24 2018.
68. Africa's first masters in interventional cardiology launched at UCT. https://www.medicalbrief.co.za/archives/collaboration-makes-much-needed-speciality-reality/. 2018.
69. Jama ZV, Chin A, Badri M, Mayosi BM. Performance of re-used pacemakers and implantable cardioverter defibrillators compared with new devices at Groote Schuur Hospital in Cape Town, South Africa. Cardiovasc J Afr. 2015;26(4):181–7. https://doi.org/10.5830/cvja-2015-048.
70. Adebayo RA, Ikwu AN, Balogun MO, Akintomide AO, Ajayi OE, Adeyeye VO, et al. Heart rate variability and arrhythmic patterns of 24-hour Holter electrocardiography among Nigerians with cardiovascular diseases. Vasc Health Risk Manag. 2015;11:353–9. https://doi.org/10.2147/vhrm.s81106.