12-2023

Improving implant training for physicians and their teams in under-represented regions

Jeilan Mohamed

Mohamed Varwani

Abdul Raqib

Emin Evren Ozcan

European Heart Journal Supplements (2023) **25** (Supplement H), H13–H21
The Heart of the Matter
https://doi.org/10.1093/eurheartjsupp/suad134

ESC
European Society
of Cardiology

Improving implant training for physicians and their teams in under-represented regions

Mohamed Jeilan[1]*, Mohamed Hasham Varwani[1], Abdul Raqib[2], and Emin Evren Ozcan[3]

[1]Department of Cardiology, Aga Khan University Hospital, 3rd Parklands Rd, Nairobi, Kenya; [2]Department of Medicine, Hospital Serdang, Selangor, Malaysia; and [3]Department of Cardiology, Dokuz Eylul University, Balcova, Turkey

KEYWORDS
LMICs;
Bradycardia;
Pacemaker;
Implant training;
Simulator-based training

The burden of cardiovascular disease is increasing globally, with low- and middle-income countries (LMICs) absorbing most of the burden while lacking the necessary healthcare infrastructure to combat the increase. In particular, the disparity in pacemaker implants between high-income countries and LMICs is glaring, partially spurned by reduced numbers of physicians and supporting staff who are trained in pacemaker implant technique. Herein, we will discuss current pacemaker implant training models, outline training frameworks that can be applied to underserved regions, and review adjunctive training techniques that can help supplement traditional training models in LMICs.

Introduction

Conventional transvenous pacemakers are well-established lifesaving therapies, needed in the management of symptoms related to bradyarrhythmia and the prevention of sudden cardiac death. On the global front, there has been a steady rise in access to pacemakers in the last five decades matching the accelerated developments in technology in this field. However, the populations of many low- and middle-income countries (LMICs) are unable to access regular pacemaker implantation services, and in countries where there is some capacity, they are mostly concentrated within a few urban facilities located in the capital cities.[1,2] According to a study published in the *Pan African Medical Journal* in 2019, the average annual implant rate of pacemakers in Africa was only 2.2 per million population, compared to the global average of 50 per million population representing a 23-fold difference. Even within Africa, many countries reported an implant rate much lower than 2.2 per million, and in some countries, there was no access at all.[3]

The poor uptake and disparity in utilization of conventional pacemakers in underdeveloped economies are multifactorial and are an area of active focus led by most of the regional arrhythmia societies and various stakeholders. The absence of technological resources including catheterization facilities and fluoroscopy services as well as the high cost of implant procedures are major contributors to low implant rates in LMICs. However, a severe lack of trained healthcare professionals and teams who can safely perform a pacemaker implantation procedure is an equally important barrier to pacemaker utilization in many regions. This can be attributed to a scarcity of cardiac implantable electronic device (CIED) implant training programmes and opportunities for physicians interested in pacemaker implant in these regions.

Data on implant training in underrepresented countries are scarce and mainly look at the trends in local implantation rates over time. The Africa-Pace missions, a humanitarian pacemaker implant programme, provided data on implant rates from 14 African countries over more than two decades. This programme resulted in an increase in local, annual implantation rates from 0.04 (95% confidence interval: 0.02 to 0.06) to 0.65 (95% confidence interval: 0.54 to 0.75) per million inhabitants.[3,4] Proctorship-based initiatives such as these have been met with some controversy but are challenging existing training models and have led educators to explore efficient and fit-for-purpose models

*Corresponding author. Tel: +254 716 446216, Email: jokumali@hotmail.com

that harness regional opportunities to improve local capacity without compromising outcomes.[5]

In this paper, we will review the status of implant expertise in underserved regions, the challenges faced in building capacity, review existing (traditional) models for training competent implanting teams, describe the limitations of traditional models in these regions, and explore/propose avenues to enhance local capacity. The aim of this article is to inform local policymakers and stakeholders on the components of high quality, efficient training programmes that can be delivered sustainably to underserved regions of the world.

Traditional training model

In some countries, pacemaker implantation is exclusively performed by super-specialized cardiac electrophysiologists, but in most countries, the pacemaker practitioner will be a qualified and board-certified cardiologist who has completed general cardiology training over 36 months and has taken an interest in pacemaker therapy. The 2015 ACC/AHA/HRS (American College of Cardiology/American Heart Association/Heart Rhythm Society) Advanced Training Statement on Clinical Cardiac Electrophysiology (EP) defines three levels of training.[6] The first level is to provide at least 2 months exposure to pacing and EP. During level 2, the trainee is expected to undergo an additional elective period of at least 6 months in pacemaker implantation and follow-up at a recognized training centre. While this could occur within the duration of a general cardiology fellowship, it usually occurs within a dedicated fellowship. Level 3 competence requires an additional 12 to 24 months of training in EP. Implanting physicians will usually have to acquire and maintain additional sub-specialty board certification through ongoing practice, audit, and continuous medical education initiatives.

The established models form the basis for safe and effective implant outcomes worldwide. Training institutions that offer a formal fellowship usually have well-tested processes and tools for training, sufficient case mix arising from robust referral pathways, established human resources, and participation in peer review and governance structures. These characteristics lend themselves to continued service and training altogether. The long duration of training produces not only a competent pacemaker implanter but also a well-rounded cardiologist with exposure to multiple cardiovascular pathologies and exposure to challenging and simple cases alike. A list of implanter training guidelines from various regions is included in *Table 1*.

Impact of traditional training model in underserved regions

Most practitioners performing implants in underserved regions were trained outside their country of practice. While returning/repatriated cardiologists have been instrumental in introducing specialist services in regions that would otherwise have little or no access to this, there are several limitations to this approach. A dedicated cardiology fellowship requires the clinician to take several years away from their usual clinical duties to develop new skills, which can burden a strained workforce and lead to local loss of access to cardiovascular care. Travelling and moving abroad to receive specialized training can also be an expensive process, closing the door to many, and these programmes are also very competitive making it harder for aspiring physicians from LMICs to gain access. Equally important, many who train abroad end up never returning to their home countries due to the higher wages offered in the areas where they train.[12] Thus, this type of training model cannot be relied upon to provide a scalable solution to meet the huge unmet need in bradycardia pacing services in LMICs.

Due to a shortage of trained, specialized cardiologists in LMICs, most cardiovascular disease is managed by internal medicine specialists. The few cardiologists that are available in developing countries cannot afford to focus purely on one domain of cardiology and they will usually master multiple skills. For example, an interventional cardiologist will offer a general cardiology service and adopt expertise in CIED implant and programming, while still practicing general ambulatory cardiology and echocardiography at the same time. The model that creates a specialized electrophysiologist who only performs EP procedures can only work if the region is served by a good number of skilled cardiologists in all other subspecialties.

Lastly, traditional fellowships in high-volume centres are not set up to address the challenges of providing pacemaker services in resource-constrained environments. Most training institutions train individuals rather than teams, and a trained implanter requires a supporting staff (nurses, technicians, and etc.) who have the allied skills to support an implant. Thus, without that supporting team, a freshly trained implanter who decides to practice in an underserved region may lose their skills while waiting for the resource infrastructure to match the demands.

The components of an efficient training programme for underserved regions

An ideal pacemaker implanter training programme will be focused, fast-tracked, and efficient. Training should be geared towards a whole pacemaker team, which includes at least two implanters and two allied health professionals (usually pacemaker nurses) and provides experience with implanting CIEDs in multiple clinical scenarios using technology from more than one manufacturer. There must also be the development of an implanting infrastructure in underserved centres, and the creation of a clinical governance framework. Various bodies have proposed curricula to meet the training requirements for pacemaker implant and follow-up. One such curriculum, adapted from the 2003 NASPE (North American Society of Pacing and Electrophysiology) curriculum, can be found in *Table 1* of the Appendix.[7]

Equally important is the selection of proper candidates. Training should be prioritized for committed individuals who are supported by committed institutions. If cardiologists aren't available, those physicians with an interest in cardiology who have a foundational understanding of cardiovascular medicine and a sound knowledge of the electrocardiogram (ECG) and pacing should be considered. The characteristics of the ideal trainee and unit are listed in *Table 2*.

Table 1 Published international society guidelines for training in cardiac device implantation

Society	Guideline title	Year of publication
North American Society for Pacing and Electrophysiology[7]	NAPSE Training requirements for Cardiac Implantable Electronic Device	2003
The Cardiac Society of Australia and New Zealand[8]	Guidelines for sub-specialty training in cardiac implantable electronic devices: selection, implantation and follow-up	2013
ACC/AHA/HRS[6]	Advanced Training Statement on Clinical Cardiac Electrophysiology	2015
British Heart Rhythm Society[9]	Standards for implantation and follow-up of Cardiac rhythm management devices in adults	2018
Canadian Heart Rhythm Society[10]	Canadian Heart Rhythm Society Task Force Report on Physician Training and Maintenance of Competency for Cardiovascular Implantable Electronic Device Therapies: Executive Summary	2021
Africa Heart Rhythm Association[11]	Cardiac Pacing Training in Africa: Endorsed by the Africa Heart Rhythm Association (AFHRA)	2020

Table 2 Ideal requirements of physician and hospital candidates to enter a fast-track training model

Physician profile prerequisites	• Clinical expertise that includes good understanding of ECG and electrophysiology basics
	• Basic surgical and transvenous skills
	• Leadership capacity to invite referrals and build a pacemaker implantation team
	• The hierarchy of experience would favour offering training in this order according to who is available in the underserved region as follows:
	  • Cardiologist or cardiology fellow
	  • Cardiac surgeon or endovascular specialist
	  • Intensive or emergency care specialist, or internal medicine physician (with cardiovascular medicine interest)[a]

Hospital	• Readiness and commitment of hospitals to provide trainees with cases • Access to patient referrals • Access to pacemakers and pacemaker implant support technology • Infrastructure (cathlab or surgical suite with good quality C-arm and ECG monitoring) • Governance structure that supports clinical privileges for the trainee • Quality assurance mechanisms in place

[a]Depending on local regulations and institutional support to provide clinical privileges.

Lastly, before embarking on setting up an implanter training programme, one must first evaluate the local resources and what the needs are. It is more efficient to build on existing infrastructure than to set up a completely new programme. Also, it is important to offer training for prospective implanters and their teams within their geographical locale where available, which will harness local expertise and partnerships.

Training frameworks

There are several types of training frameworks that can be implemented for pacemaker implanter training. Depending on the region and its specific needs or available resources, one or more of these frameworks can be used.

Observerships

Observerships involve watching procedures being performed by an expert operator team, usually at a high-volume centre. The trainees, while not directly participating in the procedure, benefit from witnessing, first-hand, a specific skill being practiced in real life. Observerships are usually short-term, are cheaper, and are especially useful when physicians and their allied teams cannot leave their centres for a prolonged period. This type of training is most useful at the beginning of training programmes where teams can witness the broad requirements and set-up of a pacing service. While this type of training is useful for introducing a prospective implanter and their team to pacemaker implant technique, it is especially useful for them to get a sense of the workflow and set-up that goes into the implant procedure. Observerships can also be helpful for operators who want to revisit certain techniques that do not require surgical contact with a patient such as implant programming. In such cases, communication with the training centre in advance to determine the learning goals and scheduling the appropriate cases will facilitate the objectives of the observership.

Proctorships

In proctorships, implant experts will mentor skilled apprentices to aid them in further refining their skills.

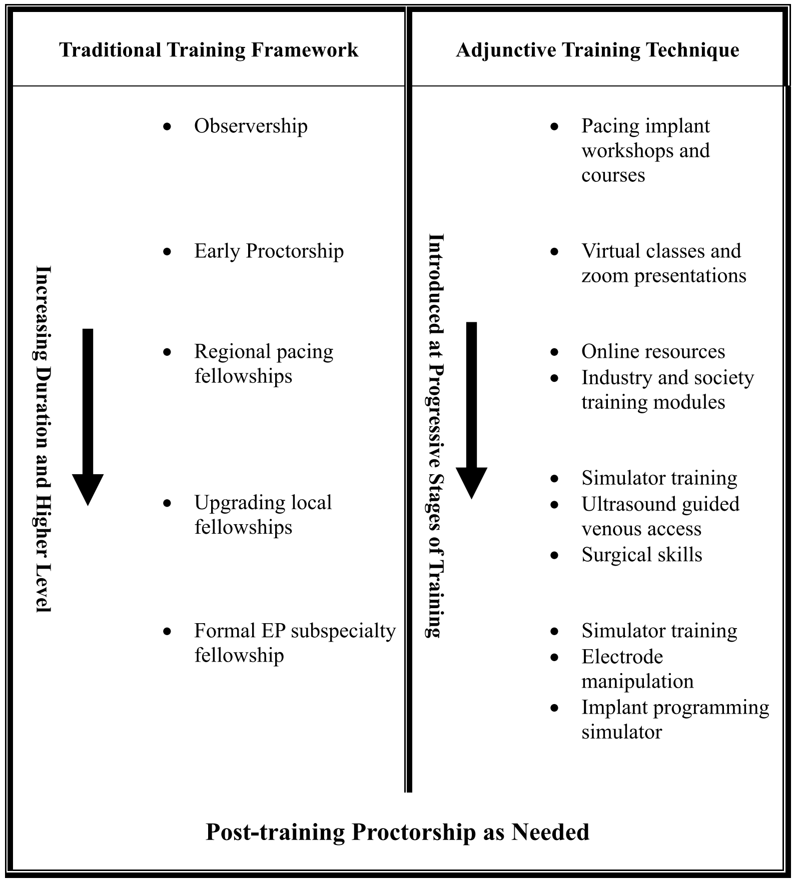

Figure 1 The relationship between various training frameworks and adjunctive training techniques.

This model is usually a humanitarian effort and involves implant teams (led by a CIED implant expert) that travel to centres and train locally identified implanters, who are assumed to have working knowledge and skills pertaining to the technique. This training is hands-on and involves patients who have been pre-identified for participation in these camps. The training provides a rich opportunity to address gaps in training but should be accompanied by a didactic programme and an evaluation of local needs before and after the proctorship.

Proctorships require persistent and concerted efforts by both the local team and dedicated international partners, and there are several drawbacks to this framework. Although scalability has been demonstrated with this approach, most camps occur as isolated events that rarely impact local capacity. Also, due to the short time frame of these training sessions, there is the risk that the trainees eventually lose the skills. Lastly, these programmes have no curriculum, and verification of competence or skill transfer is also not standardized.

However, proctorships can be very effective in refinement of skills such as coronary sinus vein lead cannulation where the implanter can already perform right sided lead placement. Additionally, the introduction of cardiac resynchronization therapy (CRT) in many parts of the world was built on these proctorship processes in the early phase of CRT, and in parts of Africa, these programmes are continued to be utilized.

Dedicated regional pacing fellowships

A more standardized framework is the implementation of regional pacing fellowships, which is a short, focused turnkey approach to pacemaker implant training for physicians, cardiologists, and their teams. The Pan African Society of Cardiology (PASCAR) fellowship in cardiac pacing is a successful initiative on the African continent that has trained physicians in underserved parts of Kenya, Tanzania, Sierra Leone, Zambia, and Ethiopia through an intensive 6-month, hands-on programme at institutions in Khartoum, Sudan, and Cape Town, South Africa. In 2020, more than 250 pacemakers had been successfully implanted by beneficiaries of this programme. A major strength of this framework is that it often provides a similar environment to where the trainee will eventually practice in terms of equipment and facilities. With the PASCAR model, training was organized through the trainee's institution and candidates were bound to return to their sponsoring institute to begin their own practice.

Upgraded local general cardiology fellowships

Although the availability of cardiology training opportunities in many regions varies, cardiovascular fellowships are slowly emerging in some countries. While the focus of these fellowships is mainly non-procedural, implant training can potentially be incorporated. Incorporating implant training within local cardiology

Table 3 **The steps of a pacemaker implant and the teaching methods and assessments that may be used**

Steps of implant procedure	Observerships	Didactic physical	Didactic virtual	Human cases	Simulator cases	Allied team involvement	Assessment format
Patient selection and indications	++	+++	+++	+++	+	++	W
Patient preparation (pre-procedure)	++	+++	+++	+++	+	+++	W/S
Theatre/cathlab preparation	+++	+	+	+++	+	+++	R
Programmer set-up	+++	++	++	+++	+	+++	R/S
Infiltration and incision	++	+	+	+++	–	+	-
Fashioning the pocket	++	+	+	+++	–	+	R
Vascular access—cephalic	+	+	+	+++	–	+	R
Vascular access—axillary vein	++	++	++	+++	+++	+	R/S
Electrode placement	+	+	+	+++	+++	+	R/S
Electrode screwing	++	++	+	+++	+++	+	R/S
Electrode suturing	+	+	+	+++	+++	+	R/S
Electrogram (EGM) signals	+++	++	++	+++	+++	+++	W/R/S
Threshold testing	++	++	++	+++	+++	+++	R/S
Sensing testing	++	++	++	+++	+++	+++	R/S
Impedance testing	++	++	++	+++	+++	+++	R/S
Stability testing	++	++	++	+++	+	++	R/S
Pocket closure	++	+	+	+++	+	+	W/R
Post-implant checks	++	+	+	+++	+++	+++	R/S

Didactic virtual teaching includes online resources, YouTube style course material, live or recorded cases, and webinars; simulators include wet-lab, animal models, digital/virtual reality simulation models for electrode manipulation, vascular access, and device programming and interrogation. The more + symbols, the better the approach for the indicated step.

W, written exam; S, simulated case; R, real human case.

fellowships that haven't previously offered, this is the lowest hanging fruit for underserved regions with existing fellowship programmes. These can be at the fellowship centre or in partnership with nearby pacemaker implant centres. Factors that need to be considered include the length of training, availability of implant facilities, expertise at the training centre, and implant volume. The first cardiology fellowship in East Africa to include pacemaker training was launched in 2016, and trainees spent 6 months rotating in the EP lab and participating in around 50 implants. Most graduates of this programme have demonstrated competence in dual chamber pacemaker implant by the end of their fellowship.

Adjunctive techniques

In addition to more formal training programmes, there is also the opportunity to implement non-traditional training frameworks. With these training methods, the exposure to the implant technique will ordinarily be less and will need to be augmented by structured medical education techniques to ensure that the skill and knowledge are acquired by the trainee (*Figure 1*).

Simulator training, pacing, and implant workshops

Simulation pacemaker implant procedures cannot supplant the value of performing on actual patients, but it does hold great value in allowing the trainee to refine their muscle memory technique. By utilizing simulators, operators can develop a more comprehensive understanding of case dynamics and refine their manual dexterity at a reduced cost to performing on patients.[13]

Simulators may be used in various critical steps of the implant (*Table 3*, *Figure 2*) as follows:

(1) Surgical incision and suture: Surgical simulation pads with multiple layers serve as effective and cost-efficient tools for teaching incision and suture techniques. Advanced mannequins provide scenarios for incision, pocket preparation, vessel ligation, bleeding management, and electrode fixation in the pectoral region.
(2) Venous access (e.g. axillary vein): Safe venous puncture is crucial. Simulators developed for central venous puncture applications have been adapted to an ultrasound-guided approach. The adoption of this technique may prevent complications and improve the confidence and efficiency of the implanter.
(3) Electrode manipulation and placement: Digital simulators are predominantly employed in this domain. They offer the advantage of comprehending fluoroscopic anatomy without exposure to radiation. Furthermore, virtual reality facilitates the simulation of operations in an exceptionally realistic setting akin to an operating room. These simulators do not perfectly emulate the touch and feel of a real-life implant, but the technology is very close. Nonetheless, observing the compatibility and movements of different electrodes with different

Figure 2 Examples of training during the Africa STEMI 2023 symposium that was organized by PASCAR and AFHRA. Training of physicians during a device workshop using an electrode manipulation simulator (top left), surgical skills animal model (bottom left), pacemaker programming simulator (top right), and vascular access on a mannequin (bottom right).

stylets on actual materials is helpful, and with appropriate stewardship, the degree of manipulation that is safe and not harmful can be taught. More modern simulators add case scenarios of varying complexities, and the technology is advancing at a rapid pace. With appropriate proctoring, this approach helps overcome the limitations of digital simulators, such as the absence of tactile feedback and accurate torque replication.

(4) Cardiac electrophysiology knowledge: Threshold and sensing tests can be studied with digital simulators. Scenarios in the device programmers are realistic and add to the case complexity. Employing standardized interfaces will help facilitate transition to real cases after training. Case-based studies and trainings on troubleshooting should be repeated as implantation training advances.

Virtual classes

With access to the internet expanding and use of smartphones becoming commonplace, fundamental theoretical training can be conducted online, enhancing trainees' competence for subsequent face-to-face training sessions. Virtual classes eliminate transportation and accommodation costs, which can provide education opportunities for more people regardless of distance.

The evolution of communication technologies has enabled remote proctorship, wherein participants can engage in a remote case using virtual reality glasses. Remote support is instrumental in bolstering operators' self-assurance during initial cases and resolving any issues that may arise. Nevertheless, it is essential to bear in mind that surgical mastery is an art acquired through mentorship and apprenticeship. Ideally, trainees should spend their initial hands-on training stages in high-volume centres for as long as possible. The aforementioned methods can serve to expedite this process.

Assessment of training and quality assurance

Training outputs

A well-rounded implanting physician who can safely and independently offer a pacemaker implant service will have developed the following skills:

(1) Ability to make a diagnosis of conditions amenable to pacemaker therapy, and understand the indications, limitations, and contraindications of a CIED implant.
(2) Having proficiency in techniques of transvenous implantation. This is the most time-intensive training phase and requires a step-by-step demonstration of the implant technique. Initially, the trainee will be taught the steps while assisting, and gradually transition to perform the entire procedure as first an operator under supervision and later independently.
(3) Anticipation, recognition, and management of complications. This is a continuous learning process that comes with experience and procedural exposure. Training at a high-volume centre can enhance this, but the learning process will usually continue throughout an implanter's career. Sharing unique experiences in scientific fora using various

Table 4 Minimum requirements of training in a comprehensive non-traditional training programme that utilizes adjunctive training methods

Didactic	• Curriculum completion, attainment of competency in knowledge, and other assessments

Volume of implants	• Minimum of 30 implants
	  • Primary implanter in all implants
	  • Includes simulated cases (no more than 5)
	  • Proctored (10–20%)

Training time period	• Shortest time feasible • Active for at least 3 months • Recommended completion within 12 months (no longer than 24 months)
Certification responsibility	• Certification can be provided as appropriate by local societies/university/training centres that are running the training programme • Locally appropriate accreditation of the certificates by relevant authorities
Qualification responsibility	• Hospital
Training of allied staff and supporting teams	• Run in parallel to the physician implanter training • Augmented with short observerships at high-volume centres, didactic sessions, and online resources
Other	• Develop a referral pathway for less acute cases and complications that require more experienced operators

social media and formal publications can help create awareness among other implanters.

(4) Care in the immediate and intermediate post-implant period. This includes wound management, device interrogation, and device programming to meet the needs of the patient and address early issues. Device follow-up requires a comprehensive understanding of pacemaker programming modes, timing cycles, and the ability to recognize and troubleshoot deviations and events. This is often supported by the allied health professional such as a trained nurse or a medical device technician.

Testing of knowledge and proficiency

Measurements to assess the effectiveness and impact of pacemaker implant training over time should be utilized to provide a platform for continuous improvement and validate the training methods. Periodical group meetings (physical or virtual) with other implanters, mentors, and experts can provide continued learning and improvement in an informal forum. Quality assurance of the training programmes should include testing and application of the acquired skills. A knowledge-based exam that tests the theoretical knowledge of candidates and the application of knowledge may borrow from existing platforms (e.g. International Board of Heart Rhythm Examiners certification). A simplified version that tests knowledge on bradycardia pacemakers may suit the needs of a programme focusing on bradycardia therapy.

In regard to assessment of a trainees' implant procedure skills, three foundational, globally applicable, and scalable metrics should be collected at each new centre including as follows: (i) the complication rate at 30 days, (ii) procedure/fluoroscopy time, and (iii) the number of patients implanted. For a candidate to achieve competence in the implantation and management of permanent pacemaker implants, ESC/EHRA (European Society of Cardiology/European Heart Rhythm Association) recommends a minimum of 50 implants (30 as primary operator) and 250 follow-up/device programming, whereas the HRS recommends a minimum of 50 implants (all as primary operator), 100 follow-up/device programming, and another 30 CIEDs revision or replacements.[6,14] The use of adjunctive methods may help provide simulated or virtual training experiences and lead to lower total numbers. For a fast-tracked programme, face-to-face physical patient contact may not allow this case load. Incorporating adjunctive techniques may allow adjustments to the existing recommended training and competency caseloads. Our proposed adjustments are included in *Table 4*.

Conclusions

An efficient training pathway that utilizes a combination of several medical educational tools can be introduced to improve pacemaker training in LMICs. The model should be supplemented with quality assurance and governance structures to ensure that safety and efficacy are maintained. The models described above can be introduced in many settings but is most urgently needed in underserved regions where access to pacing remains a significant concern and training programmes are scarce or non-existent. In areas where the need is greatest, the training should be broad enough to ensure that allied health professionals who will support a pacing service are also included. Most importantly, the training model should be tailored for the needs of the specific region for which it is intended in order to have the greatest impact.

Funding

This paper was published as part of a supplement financially supported by Medtronic plc.

Conflict of interest: None declared.

Data availability

No new data were generated or analysed in support of this research.

Appendix

Appendix Table 1 An outline curriculum for didactic pacemaker training (excerpted and adapted from the NASPE guidelines 2003)

- **History:** Symptoms that suggest a pacing system complication, e.g. loss of capture, extracardiac stimulation, inappropriate rate response, and pacemaker syndrome.
- **Physical examination:** Physical signs of pacing system complications. Expected appearance of pacemaker pocket and incision.
- **Mode codes:** Understand the accepted nomenclature (NBG pacemaker code) for pacing modes.
- **Indications for implantation of devices for bradyarrhythmias and tachyarrhythmias:** Understand the current International guidelines for pacemaker and ICD indications. Proper prescription of, contraindications for, and understanding of complications of single chamber, dual chamber, rate adaptive, and antitachycardia devices.

Device and technology characteristics

- Physiology of electrical stimulation and genesis of the endocardial electrogram.
- Basic pulse generator design and function.
- Understanding interactions of pacemakers with drugs and implantable cardioverter defibrillators.
- Pacing system analyser (PSA) measurements and electrical testing at time of implantation, including minimally acceptable PSA measurements, excitation threshold measurements, and endocardial electrogram measurements.
- Methods for pacemaker follow-up, including the use of programmers.
- **Electrocardiography:** Interpretation of paced electrocardiograms.
- **Telemetered pacemaker data:** Programmed data, measured data, rate histograms, electrograms, and other diagnostic pacemaker data.
- **Programming:**
  - Sensing threshold.
  - Stimulation threshold.
  - Atrioventricular conduction assessment.
  - Ventriculoatrial conduction assessment.
  - Assessment of chronotropic incompetence.
  - Optimization of haemodynamic function.
  - Initiation and management of pacemaker-mediated tachycardia.
  - Uses of available programmable pacing modes, rate programming, output programming, sensitivity programming, refractory period programming, rate adaptive parameters.
  - Complications of programming: loss of capture, rate changes, oversensing, undersensing, cross-talk. Transtelephonic monitoring: understanding of its role in follow-up.
  - Troubleshooting: pulse generator failure (battery depletion), lead failure, rate changes, sensing abnormalities, non-capture, cross-talk. Indicators of battery depletion, methods for appropriate monitoring, and detection of indicators.

Differential diagnosis of device malfunction

Recognition and management of post-implantation complications

- A thorough knowledge of recognizing and treating pacemaker surgical complications and emergencies.
- Throughout at least a portion of the training, responsibility for emergency treatment of patients with pacemakers. This will allow the trainee to obtain experience in dealing with acute device related problems, including those arising from temporary pacing and the use of emergency transcutaneous pacing techniques.
- Participation in at least 100 follow-up visits of patients with implanted arrhythmia control devices. The trainee should be the primary operator and evaluator during the 100 follow-up appointments. The trainee must demonstrate knowledge of the approach to routine follow-up and troubleshooting of implantable devices. Hands-on assessment should include interpretation of paced and non-paced electrocardiograms, interrogation and programming of devices, evaluation of pacemaker dependency, and interpretation of telemetry information. Active participation in diagnosis, prescription, and management for 50 patients who require device implantation is desirable.

References

1. Mond HG, Proclemer A. The 11th world survey of cardiac pacing and implantable cardioverter-defibrillators: calendar year 2009—a World Society of Arrhythmia's project. *Pacing Clin Electrophysiol* 2011;**34**:1013–1027.
2. Alyesh D, Pavri BB, Choe W, Chandara M, Sani MU, Phan PD *et al.* Advancing global equity in cardiac care as cardiac implantable electronic device reuse comes of age. *Heart Rhythm O2* 2022;**3**:799–806.
3. Jouven X, Diop BI, Narayanan K, Adoubi At, Ba SA, Balde D *et al.* Cardiac pacing in sub-Saharan Africa: JACC international. *J Am Coll Cardiol* 2019;**74**:2652–2660.
4. Talle MA, Bonny A, Scholtz W, Chin A, Nel G, Karaye KM *et al.* Status of cardiac arrhythmia services in Africa in 2018: a PASCAR Sudden Cardiac Death Task Force report. *Cardiovasc J Afr* 2018;**29**:115–121.
5. Bonny A, Ajijola OA, Jeilan M, Sani M, Yousef Z, Yuyun MF *et al.* Cardiac pacing in sub-Saharan Africa. *Cardiovasc J Afr* 2020;**31**:3–4.
6. Zipes DP, Calkins H, Daubert JP, Ellenbogen KA, Field ME, Fisher JD *et al.* 2015 ACC/AHA/HRS advanced training statement on clinical cardiac electrophysiology (a revision of the ACC/AHA 2006 update of the clinical competence statement on invasive electrophysiology studies, catheter ablation, and cardioversion). *J Am Coll Cardiol* 2015;**66**:2767–2802.
7. Gura MT, Bubien RS, Belco KM, Taibi B, Schurig L, Wilkoff BL. North American Society of Pacing and Electrophysiology. Standards of professional practice for the allied professional in pacing and electrophysiology. *Pacing Clin Electrophysiol* 2003;**26**:127–131.
8. Zealand TCSoAaN. Guidelines for sub-specialty training in cardiac implantable electronic devices: selection, implantation and follow-up. https://www.csanz.edu.au/wp-content/uploads/2014/12/Sub_spec_Training_CIED.pdf.
9. Society BHR. Standards for implantation and follow-up of Cardiac rhythm management devices in adults. https://bhrs.com/wp-

content/uploads/2019/03/180122-sp-BHRS-Standards-Implantation-and-Follow-Up-of-CRM-Devices-in-Adults.pdf.

10. Yee R, Karim SS, Bashir J, Bennett MT, Exner DV, Guerra PG *et al*. Canadian Heart Rhythm Society Task Force report on physician training and maintenance of competency for cardiovascular implantable electronic device therapies: executive summary. *Can J Cardiol* 2021;**37**:1857–1860.
11. Rwebembera J, Jeilan M, Ajijola OA, Talle M, Sani MU, Karaye KM *et al*. Cardiac pacing training in Africa: endorsed by the Africa Heart Rhythm Association (AFHRA): JACC International. *J Am Coll Cardiol* 2020;**76**: 465–472.
12. Vervoort D, Velazco-Davila LD. Closing the gap by filling the gaps: leveraging international partnerships to train the world's cardiac surgical workforce. *J Thorac Cardiovasc Surg* 2020;**160**:e51–e52.
13. Mascheroni J, Mont L, Stockburger M, Patwala A, Retzlaff H, Gallagher AG. The imperative of consistency and proficiency in cardiac devices implant skills training. *Open Heart* 2021;**8**:e001629.
14. Blomström-Lundqvist C, Traykov V, Erba PA, Burri H, Nielsen JC, Bongiorni MG *et al*. European Heart Rhythm Association (EHRA) international consensus document on how to prevent, diagnose, and treat cardiac implantable electronic device infections—endorsed by the Heart Rhythm Society (HRS), the Asia Pacific Heart Rhythm Society (APHRS), the lLatin American Heart Rhythm Society (LAHRS), International Society for Cardiovascular Infectious Diseases (ISCVID) and the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS). *Europace* 2019;**22**:515–549.