Pediatric cardiology: Is India self-reliant?

Annals of Pediatric Cardiology (APC) is a global journal and has a vision to further expand its footprint across the world.[1] Indian health care has seen unprecedented growth in the last few decades, which has further received a great boost with the announcement of "Make in India" and "Atmanirbhar Bharat Abhiyan (self-reliant India program)" by the Government of India. The editorial board of APC has decided to dedicate the current issue to "Research Made in India," an attempt to highlight the progress of pediatric cardiology in India. Besides, this editorial tries to address a few critical questions: "Has India become self-reliant in the field of pediatric cardiology in terms of delivering clinical care, in training health professionals, and in addressing research questions relevant to India?"

SELF-RELIANCE IN THE DELIVERY OF PATIENT CARE

The first pediatric cardiac surgery was performed in India way back in 1949 and the first Indian center that sought to deliver pediatric cardiac care was established in the 1960s.[2] After considerable hiatus until the mid to late 90s, multiple pediatric cardiac centers were established. Many of these are now offering high-quality pediatric cardiac and surgical services. In the current scenario, we need to address issues related to availability, accessibility, and affordability of pediatric cardiac care in India.

A status report in 2005 estimated the number of pediatric cardiac centers in India at 14,[3] and the number stands now at 90 based on an inquiry done among the members of Pediatric Cardiac Society of India (PCSI). It only seems that pediatric cardiac care in India has grown from its infancy to childhood. The rate of increase in the number of hospitals is particularly steep in the past two decades with newer cities such as Jaipur, Raipur, Coimbatore, Bhubaneshwar, Palwal, and a few more added to the map of pediatric cardiac care in India. Despite this, patients face a variety of challenges in accessing standard pediatric cardiac care. Most of the pediatric cardiac centers are concentrated in major cities, and most of them are privately run. The distribution of pediatric cardiac centers is also not uniform across the country. For instance, Kerala has eight centers offering neonatal cardiac surgeries for an estimated 4.5 lakh annual childbirths. In stark contrast, the most populous states of India, namely Uttar Pradesh and Bihar, with estimated annual childbirth of 48 and 27 lakhs, respectively (Census of India, 2012), do not have a center capable of performing neonatal cardiac surgery. Hence, all sick neonates born in these states who need emergency cardiac surgery have to be transported, often by trains, buses, or occasionally private ambulances to the nearest cardiac centers, which are usually hundreds of kilometers away.

Many Indian pediatric cardiac programs have shown the way in terms of cost-efficiency. Most of the cardiac procedures are performed at a fraction of the cost compared to Western countries. For instance, an arterial switch surgery costs anywhere between 800 and 6000 USD in India, depending on the nature of the hospital, while the approximate cost for the same procedure exceeds 50,000 USD in the United States.[4] However, lack of insurance and dependency on out-of-pocket expenses have remained major hindrances, making pediatric cardiac care largely unaffordable for the average Indian family. Fortunately, several funding opportunities have emerged for children needing a cardiac surgery over the past decades. Janani Shishu Suraksha Karyakaram (JSSK), a program under the National Health Mission, intends to eliminate the out-of-pocket expenses incurred by families toward the treatment of infants in public health facilities. Ayushman Bharat, other state government insurance schemes for the underprivileged, and funding from nongovernmental organizations have made financial assistance for pediatric cardiac procedures available for most Indians. However, a lack of awareness about these schemes among parents remains a major constraint.

Developing subspecialties of pediatric cardiac care in India is the need of the hour. Whereas interventional and surgical pediatric cardiology services are reasonably well established, especially in the Southern and Western parts of India, the rest of subspecialties lack an organized structure. Even in these parts, the rates of antenatal diagnosis of congenital heart disease (CHD) are dismal. Some specialized services such as inherited cardiovascular disease clinics[5] and pediatric heart transplant programs are getting established. However, organized adult CHD and pediatric electrophysiology services are almost nonexistent. There are no dedicated care providers for adults with CHD, with both trained

adult cardiologists who lack CHD knowledge and pediatric cardiologists who lack expertise in managing adults, ultimately ending up caring for these patients. There are no dedicated pediatric electrophysiologists, and electrophysiology services for children with CHD are provided by adult electrophysiologists only. There are very few personnel qualified as pediatric cardiac intensivists, and there is really no system to train them.

In delivering pediatric cardiac care, India has taken the first steps toward being self-sufficient. There is a lot that needs to be done for improving the access and the quality of care. The available resources, though limited, are to be utilized judiciously. Every state should establish enough pediatric cardiac centers to cater to their local needs and develop an integrated model of care for children with heart diseases. Lessons should be learned from programs like the Hridyam, a unique initiative by the Government of Kerala, aimed toward early detection and management of critical CHDs. At the hospital level, quality and outcomes are variable across India. Nationwide audits and quality control initiatives are needed. We need to set up centers of national excellence for uncommon pediatric cardiac conditions such as cardiomyopathies, inherited cardiovascular diseases, and pulmonary hypertension.

SELF-RELIANCE IN TRAINING OF PERSONNEL

The US had 2966 pediatric cardiologists in 2019, with a ratio of one pediatric cardiologist per 29,196 population.[6] In contrast, India has only 300 pediatric cardiologists for a population of 1.39 billion with a ratio of one per 4,500,000 population. The comparison is even more dismal for pediatric cardiac surgeons, though accurate numbers are not available. An additional challenge is to motivate younger generation cardiovascular surgeons to take up the subspecialty of pediatric cardiac surgery. The number of centers offering pediatric cardiology fellowship programs has increased over the years. Yet, the total number of fellows trained (Doctorate in Medicine and Diplomate of National Board) is around 35 per year only. Unlike the Western world, where most fellows (59%) pursue advanced fellowships after their pediatric cardiology fellowship,[7] such opportunities are seldom available in India. To bridge the gap, PCSI has instituted fellowship programs in selected subspecialties of fetal cardiology, electrophysiology, and pediatric cardiac intensive care involving centers of excellence across the country. India needs to invest in training specialized nurses to provide critical care for children with CHD, a neglected field. The number of training centers, quality of training, and availability of advanced subspecialty training must further improve in India.

SELF-RELIANCE IN RESEARCH

In contrast to patient care and education, we are a lot less self-sufficient in terms of research in pediatric cardiology. India is a net consumer than the producer of original research in the field. In recent years, the major Indian contributions to pediatric cardiac surgery include two-stage arterial switch surgery,[8] delayed primary arterial switch surgery,[9] and an innovative approach of integrated extracorporeal membrane oxygenation circuit[10] for late presenters with transposition of great arteries (TGA) and intact ventricular septum. In the field of noninterventional pediatric cardiology, noteworthy Indian contributions include echocardiographic screening for rheumatic heart disease,[11] drug therapy for children with idiopathic pulmonary hypertension[12] and adolescents with Eisenmenger syndrome,[13] use of thiamine to reverse infantile pulmonary hypertension,[14] management of nonspecific aortoarteritis,[15] and lifestyle diseases in children.[16,17] Off-label use of devices for perimembranous ventricular septal defects[18] and Gerbode defect,[19] ductal stenting in late presenters with TGA,[20,21] and balloon-assisted atrial septal defect device deployment technique[22] are some of the major contributions to the field of interventional pediatric cardiology. Truly Indian innovations include a percutaneous transvenous aortic valve technology (MyVal; Meril Life Sciences Pvt. Ltd, India) and a multifunctional occluder device known as Lifetech™ Konar-MF.[23]

Indian contributions to pediatric cardiac research could have been a lot better, considering the number of patients and the quality of expertise. It is unfortunate that none of the Indian articles featured among the most influential 100 articles compiled by Eynde *et al.*[24] in the field of CHD published between 2000 and 2020. This is despite the fact that research activity in Indian pediatric centers has increased exponentially, and the total number of articles published from India is at its peak in recent years. One of the main reasons for this paradox is that the research performed in India is not focused on areas that interest the Western world.

For this editorial, the most cited Indian articles published over 30 years between 1991 and 2020 were compiled [Table 1]. The methodology used for compiling the list and relevant references is outlined in Supplementary Appendix 1 and 2. Such an approach focusing on citations, especially in a field known for low citation scores, has an inherent bias toward older articles and articles focusing on popular areas. Yet, this exercise presents some important learnings. Most of the impactful Indian researches in pediatric cardiology over the past three decades have come from only a few select institutions involving a group of dedicated clinical researchers. Furthermore, most of these articles

Table 1: Most cited Indian articles published in the field of pediatric cardiology over 30 years between 1991-2020

Serial number	Title	First and corresponding author(s)	Journal	Publication year	Number of citations
A	**Congenital heart disease**				
1	Phosphodiesterase-5 inhibitor in Eisenmenger syndrome: A preliminary observational study[13]	Mukhopadhyay S	*Circulation*	2006	168
2	Malnutrition in children with congenital heart disease (CHD) determinants and short term impact of corrective intervention [S1]	Vaidyanathan B	*Indian Pediatr*	2008	106
3	Therapeutic guidelines for congenital complete heart block presenting in pregnancy [S2]	Dalvi BV	*Obstet Gynecol*	1992	103
4	Echocardiographic diagnosis of aneurysm of the sinus of Valsalva [S3]	Dev V	*Am Heart J*	1993	101
B	**Acquired heart disease in children**				
5	Obesity in Indian children: Time trends and relationship with hypertension[16]	Raj M, Kumar RK	*Natl Med J India*	2007	283
6	Echocardiographic evaluation of patients with acute rheumatic fever and rheumatic carditis [S4]	Vasan RS, Shrivastava S	*Circulation*	1996	219
7	Prevalence and outcome of subclinical rheumatic heart disease in India: The rheumatic study [S5]	Saxena A	*Heart*	2011	174
8	Chronic oral sildenafil therapy in severe pulmonary artery hypertension[12]	Kothari SS	*Indian Heart J*	2002	104
9	Does endomyocardial biopsy aid in the diagnosis of active rheumatic carditis? [S6]	Narula J	*Circulation*	1993	98
C	**Interventional pediatric cardiology**				
10	Transcatheter closure of congenital ventricular septal defects: Experience with various devices [S7]	Arora R	*J Interv Cardiol*	2003	309
11	Transcatheter device closure of ventricular septal defects: Immediate results and intermediate-term follow-up [S8]	Kalra GS, Arora R	*Am Heart J*	1999	204
12	Percutaneous transluminal angioplasty for renovascular hypertension in children: Initial and long-term results [S9]	Tyagi S	*Pediatrics*	1997	136
13	Transcatheter closure of ruptured sinus of Valsalva aneurysm [S10]	Arora R	*J Interv Cardiol*	2004	131
14	Transcatheter closure of congenital muscular ventricular septal defect [S11]	Arora R	*J Interv Cardiol*	2004	111
15	Transcatheter closure of very large (≥25 mm) atrial septal defects using the Amplatzer septal occluder [S12]	Kannan BR, Kumar RK	*Catheter Cardiovasc Interv*	2003	95
16	Balloon angioplasty of native coarctation of the aorta in adolescents and young adults [S13]	Tyagi S	*Am Heart J*	1992	94
17	Transcatheter closure of ruptured sinus of Valsalva aneurysm using the Amplatzer duct occluder: Immediate results and mid-term follow-up [S14]	Kerkar PG	*Eur Heart J*	2010	94
18	Transcatheter occlusion of patent ductus arteriosus in preterm infants [S15]	Francis E, Kumar RK	*JACC Cardiovasc Interv*	2010	86
19	New technique for device closure of large atrial septal defects[22]	Dalvi B	*Catheter Cardiovasc Interv*	2005	83
D	**Pediatric cardiac surgery**				
20	Sinus of Valsalva aneurysms: 20 years' experience [S16]	Choudhary SK, Bhan A	*J Card Surg*	1997	108
21	Histopathology of the right ventricular outflow tract and its relationship to clinical outcomes and arrhythmias in patients with tetralogy of Fallot [S17]	Chowdhury UK	*J Thorac Cardiovasc Surg*	2006	102
22	Univentricular repair: Is routine fenestration justified? [S18]	Airan B	*Ann Thorac Surg*	2000	101
23	Mitral valve repair in a predominantly rheumatic population: Long-term results [S19]	Choudhary SK, Kumar AS	*Tex Heart Inst J*	2001	89
E	**Review Articles**				
24	Obesity in children and adolescents [S20]	Raj M	*Indian J Med Res*	2010	364
25	The epidemiology of Kawasaki disease: A global update [S21]	Singh S	*Arch Dis Child*	2015	220
26	Rheumatic fever and rheumatic heart disease: The last 50 years [S22]	Kumar RK, Tandon R	*Indian J Med Res*	2013	205
27	Congenital heart disease in India: A status report[3]	Saxena A	*Indian J Pediatr*	2005	173
28	Revisiting the pathogenesis of rheumatic fever and carditis [S23]	Tandon R, Narula J	*Nat Rev Cardiol*	2013	108
29	Assessment of operability of congenital cardiac shunts with increased pulmonary vascular resistance [S24]	Viswanathan S, Kumar RK	*Catheter Cardiovasc Interv*	2008	98
30	Gender bias in child care and child health: Global patterns [S25]	Khera R, Ramakrishnan S	*Arch Dis Child*	2014	90

Supplementary references S1–S25 are listed in Appendix 2

concentrated on relevant Indian issues, prevalent tropical diseases, or introduced niche ideas. They offer the young Indian pediatric cardiac specialists an inspiration and motivation to aim higher and encourage them to focus on issues that are pertinent to Indian patients.

Focused issue on research "Made in India"

In this issue of Annals, we decided to focus on Indian research articles, and it reflected a lot of our strengths. All the major Indian pediatric cardiac centers are represented, covering various aspects of pediatric cardiology including intensive care,[25] anesthesia,[26] fetal cardiology,[27] electrophysiology,[28] and heart transplantation,[29] fields in which articles published from India are limited.

The PCSI COVID-19 registry[30,31] is the first major collective effort from 24 pediatric cardiac centers across India. The first of the two papers offers a bird's eye view of what happened to pediatric cardiac care in India during the COVID-19 pandemic. It is heartening to see that emergent cases received appropriate care despite mounting challenges.[30] The second paper confirms the popular belief that the outcome of unoperated children with serious CHD could be compromised when they acquire a COVID-19 infection.[31] The accompanying editorial proposes a call for action and describes how we can prevent the situation in future in India and other low- and middle-income countries.[32] We sincerely hope that this first collaborative registry is the beginning of brighter things to come and not a one-time affair. To make this a reality, we need strong leadership, wider participation, and persistence.

Successful percutaneous pulmonary valve implantation (PPVI) using three different percutaneous valve systems is presented[33-35] and includes the first Indian multicenter experience of Melody valve implantation.[33] These articles raise the uncomfortable question that why Indian patients should wait for 20 years to get these newer and expensive technologies. The successful off-label use of relatively cheaper Indian MyVal system in pulmonary position could help us in making the therapy more affordable.[34] However, at current costs, these therapies are out of full insurance coverage by governmental and private insurance schemes. The editorial by Kothari[36] presents a critical appraisal of follow-up of operated patients with Tetralogy of Fallot and the thoughtful application of these expensive PPVI technologies in Indian patients. Considering the various concerns with PPVI in India, a strategy to reduce the subsequent requirement for pulmonary valve replacement during the primary surgery assumes greater importance, which was the focus of two different surgical approaches described from India in the current issue.[37,38]

Randomized controlled trials, especially drug trials, are a rarity among children with CHD. A randomized study of propranolol for heart failure in infants with ventricular septal defect demonstrated reduced hospitalizations and improved outcomes.[39] Exploring novel medical therapies is important for India, as many children diagnosed with critical heart disease do not receive timely interventions. Even though definitive evidence is lacking, the importance of beta-blockers for heart failure in children is highlighted in the editorial by Buchhorn.[40] He argues for a more widespread use of beta-blockers for heart failure in children, while more evidence becomes available.

RESEARCH IN PEDIATRIC CARDIOLOGY IN INDIA: PROBLEMS AND PROSPECTS

The major reasons for the current state of pediatric cardiac research in India include lack of manpower, overwhelming patient load and clinical care, lack of dedicated time for research, lesser funding opportunities, and limited collaborative multicenter research. Research in pediatric cardiac surgery is even less compared to the field of interventional cardiology, and so is research in the fields of pediatric cardiac anesthesia and intensive care. Rarely, various subspecialties come together to perform high-quality research. The status of medical research and the reasons for it are the same across various medical fields in India and are not unique to pediatric cardiology.

Pediatric cardiac research in India is limited to a select few individuals of limited centers as stated earlier. Some of them excel in their fields and are world leaders. However, the number of such leaders is small for a country of the size of India. The most critical and urgent step needed is to increase the critical mass of persons involved in pediatric cardiac research. In this regard, it is heartening to see a few small centers thinking beyond anecdotal or uncommon case reports and coming up with innovative original research work. Importance of having our outcome data could not be overemphasized as it would help us realize how far and how fast we need to go before we could achieve self-reliance. We need to move beyond intervention-dominated research. Challenges in resource-limited settings are unique, and we need to focus on our own problems and innovate methods to resolve them. Long-term follow-up studies are difficult in the Indian system, but increased mobile phone penetration and advancements in telemedicine services provide good opportunities.

Western medical curricula have integrated research as a core activity of academic training. Basics of research methodology are systematically taught, and pathways for becoming a physician–scientist are well established. Those in academic positions are periodically evaluated on

the merits of projects and research output. Such systems are nonexistent in India even in academic institutions. Then, why do Indian physicians indulge in research? either due to compulsion to fulfill criteria for promotions or thesis requirements for their academic degrees. Only a handful are self-motivated and carry out research with an itch to solve an important problem. We need to make clinical research attractive in India by introducing both financial and nonfinancial incentives. Mentoring is another hurdle as the number of good quality mentors is limited in India. Often, mentoring is limited within the boundaries of catheterization laboratories and operating rooms in India. The pediatric cardiac community in India is witnessing a generational change. Those who are about to graduate to leadership positions need to have a futuristic vision and make a difference in research while maintaining the standards set in clinical care. In recent times, several youngsters are coming through and are importantly focused on a particular field. Many of them are inducted into the revamped editorial board of APC. Some institutions collaborate with foreign institutions and encourage young fellows and faculty, especially in their formative years, to take part in collaborative clinical work and research.

In a nutshell, critical appraisal of pediatric cardiac research in India may identify a lot of missed opportunities. However, what is already achieved is commendable considering the dismal physician per patient ratios and workload. Each missed opportunity is a chance to learn and strategize a plan. We need to concentrate on collaborative research, high-quality randomized controlled studies, meta-analysis, and systematic reviews focusing on areas relevant to India. An increase in the critical number of clinicians involved in research, motivating the younger generation, and incentivizing research activities may be the first steps ahead.

"You are what your deep, driving desire is. As your desire is, so is your will. As your will is, so is your deed. As your deed is, so is your destiny."

–Anonymous, Brihadaranyaka Upanishad

Let's change our driving desires to change the destiny of children born with heart diseases in India.

Happy Independence Day 2021!

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Conflicts of interest

There are no conflicts of interest.

Sivasubramanian Ramakrishnan
Department of Cardiology, All India Institute of Medical Sciences, New Delhi, India

Address for correspondence: Prof. Sivasubramanian Ramakrishnan, Department of Cardiology, All India Institute of Medical Sciences, New Delhi, India.
E-mail: ramaaiims@gmail.com

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SUPPLEMENTARY APPENDIXES

Supplementary Appendix 1

An attempt was made to compile the most cited articles of pediatric cardiology, pediatric cardiac surgery, and allied specialties published by Indian authors over a 30-year period (1991–2020). Articles fulfilling the following criteria were selected and those having more than 75 citations were enlisted.

Inclusion criteria

1. Publication date between 1991 and 2020
2. Major work should have been done in India, or in case of collaboratory work, the first or corresponding author must have been an Indian.

Exclusion criteria

1. Major Western guidelines where an Indian is a part of the author group are not considered
2. Article should not have been a product of the work done during foreign training.

Methods

We used various methods to compile the list which included:

1. Individual searches

Citation numbers using Google Scholar were obtained individually for all the articles published by the following authors in the specified period. This exercise was done by two experienced individuals and the list was cross-checked.

Delhi

Rajendra Tandon, Savitri Shrivastava, Anita Saxena, SS Kothari, R Juneja, S Ramakrishnan, Saurabh K Gupta, Balram Bhargava, Sandeep Seth, IM Rao, *P* Venugopal, Balram Airan, Anil Bhan, A Sampath Kumar, SK Choudhary, UK Chowdhury, AK Bisoi, Sachin Talwar, V Devagouru, Milind Hote, Palleti Rajashekar, Poonam Malhotra Kapoor, Sandeep Chauhan, N Gopinath, ML Bhatia, HS Wazir, KS Reddy, Ramesh Arora, GS Kalra, Sanjay Tyagi, Vijay Trehan, Saibal Mukhopadhyay, M Nigam, M Khalillulah, KS Iyer, Parvati Iyer, Rajesh Sharma, S Radhakrishnan, Raja Joshi, Vikas Kohli, Neeraj Awasthy, Sushil Azad, Munesh Tomar, Manisha Chakrabarty, Kulbhushan S Dagar, Ashutosh Marwah, and Smita Mishra.

Kerala

R Krishna Kumar, K Mahesh, Balu Vaidyanathan, Edwin Francis, BRJ Kannan, Suresh Nair, Sangeetha Vishwanathan, R Suresh Kumar, JM Tharakan, KM Krishnamurthy, Biju Dharan, and MS Valiathan.

Maharashtra

Snehal Kulkarni, Bharat Dalvi, K Shivprakasha, Suresh G Rao, Smruti R Mohanty, Prafulla Kerkar, Ashish Katewa, Prashant Bobhate, Supratim Sen, L Srinivas, Sripal Jain, and Swati Garekar.

Tamil Nadu

KM Cherian, K Sivakumar, Raghavan Subramanyam, Stanley John, Solomon Victor, and Robert Cohelo.

Telangana

KS Murthy, Nageshwara Rao, and Nitin Rao.

Karnataka

Devi Shetty, Sejal Shah, Jayranganath M, Anand Subramanian, Sunita Maheshwari, IB Vijayalakshmi, Colin John, PV Suresh, Prayaag Kini, and Reeta Varyani.

Others

Rohit Manoj, Surjit Singh, Krishna Manohar SR, Ravi Agarwal, HM Chinnaswamy Reddy, and GB Parulkar.

2. E-mails

An e-mail was sent to all the members of Pediatric Cardiac Society of India with a request to send the list of the most cited articles of themselves, their colleagues, and institution, which met the criteria.

3. Contacted leaders in the field

An effort was made to contact a few current leading academicians to check the list for any major omissions and commissions. A few names suggested by them were also included in the search.

Despite the best of our efforts, we could have missed a few articles inadvertently due to a variety of reasons. However, a best possible effort was made to make the list as complete and accurate as possible.

APPENDIX 2: SUPPLEMENTARY REFERENCES

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S2. Dalvi BV, Chaudhuri A, Kulkarni HL, Kale PA. Therapeutic guidelines for congenital complete heart block presenting in pregnancy. Obstet Gynecol 1992;79:802-4.

S3. Dev V, Goswami KC, Shrivastava S, Bahl VK, Saxena A. Echocardiographic diagnosis of aneurysm of the sinus of Valsalva. Am Heart J 1993;126:930-6.

S4. Vasan RS, Shrivastava S, Vijayakumar M, Narang R, Lister BC, Narula J. Echocardiographic evaluation of patients with acute rheumatic fever and rheumatic carditis. Circulation 1996;94:73-82.

S5. Saxena A, Ramakrishnan S, Roy A, Seth S, Krishnan A, Misra P, *et al.* Prevalence and outcome of subclinical rheumatic heart disease in India: The RHEUMATIC (rheumatic heart echo utilisation and monitoring actuarial trends in Indian children) study. Heart 2011;97:2018-22.

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S11. Arora R, Trehan V, Thakur AK, Mehta V, Sengupta PP, Nigam M. Transcatheter closure of congenital muscular ventricular septal defect. J Interv Cardiol 2004;17:109-15.

S12. Kannan BR, Francis E, Sivakumar K, Anil SR, Kumar RK. Transcatheter closure of very large (>or=25 mm) atrial septal defects using the Amplatzer septal occluder. Catheter Cardiovasc Interv 2003;59:522-7.

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S17. Chowdhury UK, Sathia S, Ray R, Singh R, Pradeep KK, Venugopal P. Histopathology of the right ventricular outflow tract and its relationship to clinical outcomes and arrhythmias in patients with tetralogy of Fallot. J Thorac Cardiovasc Surg 2006;132:270-7.

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S23. Tandon R, Sharma M, Chandrashekhar Y, Kotb M, Yacoub MH, Narula J. Revisiting the pathogenesis of rheumatic fever and carditis. Nat Rev Cardiol 2013;10:171-7.

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