Basic cardiovascular research in China has developed dramatically during the last decade but faces unique challenges especially to improve quality and impact. In this viewpoint, we analyzed the causes that have contributed to such accelerated research activity in the cardiovascular field and discuss ways to deal with the challenges.

Cardiovascular disease (CVD) is the major cause of morbidity and mortality in China presenting rapidly evolving public health and economic burdens. China recognizes the need to develop a modern and optimized medical care system that includes cutting edge translational biomedical research to target CVD as a fundamental ingredient. Rapidly growing financial support from government sources has fueled quantum increases in scientific output of cardiovascular basic research in China during the past decade. However, China still faces significant challenges to improve the efficiency, quality, and impact of such research, as well as to effectively address the prevention and treatment of CVD.

Chinese Cardiovascular Basic Research Output

In parallel with China’s elevation to the world’s second largest economy, scientific publications in cardiovascular research (CVR) also achieved remarkable growth. During 2006 to 2015, cardiovascular basic research publications with Chinese corresponding authors had the following characteristics (data were restricted to research articles from peer-reviewed and non-open-access journals and provided by the Shanghai Information Center for Life Sciences of the Chinese Academy of Science [CAS] based on the analysis of database of Web of Science-Science Citation Index Expanded): (1) The publications from Chinese corresponding authors in 2015 was 4.2-fold of that in 2006 (Figure 1A, left axis); (2) the percent global contribution of Chinese publications increased from 2.76% in 2006 to 9.83% in 2015 (Figure 1A, right axis).

Consistent with this, the proportion of publications from China ranked 9 in 2006 and 2 in 2012 and subsequent years. To further characterize the publication dynamics, we analyzed the productivity of the articles published in 8 representative CVR journals, including Am J Physiol-Heart Circ Physiol, Arterioscler Thromb Vasc Biol, Basic Res Cardiol, Cardiovasc Res, Circulation, Circ Res, Hypertension, and J Mol Cell Cardiol. Chinese publications in these journals increased steadily. There were 21 publications in 2006 (0.95% total) and 103 in 2015 (6.82% total). However, the publications from the United States were much higher even in 2015 (697, 46.16%), but this has been relatively stable with no percentage growth of US contributions since 2006; and (3) among the publications, the percentage of highly cited research papers (ranking among the top 1% most cited for the field based on the Essential Science Indicators database) from China was 1.11% in 2006, 1.03% in 2011, and 2.34% in 2015 by September/October (Figure 1B). These data confirm a major and continuing increase in scientific contributions from Chinese scientists to the global field of CVR. Noteworthily, although the academic impact of Chinese publications, reflected by highly cited papers, during the past 10 years has been significantly enhanced, it does not match the exceptional growth in total publications.

Intellectual property, filed and issued patents represent another measure of scientific output and innovation. On the basis of the analysis of database from Dialog Innography by the Shanghai Information Center for Life Sciences of the CAS, there were totally 19112 disclosed patents from China in the field of CVR during 2006 to 2015, representing 16% of the world total in 2006 and 31% in 2015. This ranks Chinese new patents as second in the world for 2015. However, in terms of Patent Cooperation Treaty patents in the cardiovascular area, China only contributed 1% of the world total in 2006 and 3% in 2015, with ninth rank globally. These analyses confirm the rapid increase in quantity but not necessarily quality of CVR scientific output in China. To improve quality and impact, the Chinese research culture needs to change to become more focused on original, innovative, and high-risk, high-gain/impact research.

Funding Roles

Stable increases of government investment have played a critical role in the rapid growth of Chinese CVR. The National Natural Science Foundation of China (NSFC) and Chinese Ministry of Science and Technology (MOST) are the 2 major funding agencies in China for cardiovascular basic research. Additionally, the Ministry of Education, National Health and Family Planning Commission, CAS as well as local government have also increased funding for CVR. For example, the funding by the NSFC for CVR increased to 418.5 million Ren Min Bi (RMB) in 2015 from 48.5 million RMB in 2006. In particular, the total funding number for CVR from NFSC

Xinyang Hu, Huang-Tian Yang, Yuangui Zhu, Jian’an Wang, Erdan Dong

© 2016 American Heart Association, Inc.

Circulation Research is available at http://circres.ahajournals.org
DOI: 10.1161/CIRCRESAHA.116.308063

DOI: 10.1161/CIRCRESAHA.116.308063

The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.

From the Department of Cardiology, Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, China (X.H., J.W.); Key Laboratory of Stem Cell Biology and Laboratory of Molecular Cardiology, Institute of Health Sciences, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences & Shanghai Jiao Tong University School of Medicine, Shanghai, China (H.-T.Y.); Department of Health Sciences, National Natural Science Foundation of China, Beijing, China (Y.Z., E.D.).

Correspondence to Erdan Dong, MD, PhD, Department of Health Sciences, National Natural Science Foundation of China, Beijing, 100085, China. E-mail donged@nsfc.gov.cn; or Jian’an Wang, MD, PhD, Department of Cardiology, Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, 310009, China. E-mail jian’an_wang@yahoo.com


Circulation Research is available at http://circres.ahajournals.org
DOI: 10.1161/CIRCRESAHA.116.308063)
significantly increased in recent 5 years (2011–2015) compared with the period of 2006 to 2010 (Figure 1C), concomitantly with an increase of funding to 1718.4 million RMB during 2011 to 2015 from 438.4 million RMB during 2006 to 2010 (Figure 1D).

Government funding plays a leading role in orientating output of research areas. The National Basic Research Program of China (973 Program) managed by the Chinese Ministry of Science and Technology is one of the major focused funding sources for CVR. Since 2010, the 973 Program granted 15 research projects in the cardiovascular area including circulating microRNAs, mitochondrial dysfunction in heart failure, pathogenic mechanisms of atherosclerosis and arrhythmia, vascular senescence, regulation of heart development and deficiency, and stem cells in heart failure therapy. Meanwhile, to answer the call for improving public health nationwide and promoting biomedical translational research, NSFC launched the Department of Health Sciences in 2009 to support medical science relevant basic researches associated with disease prevention, control, and treatment in China. The Department of Health Science initiated a Major Research Program in 2013 with 200 million RMB for steady and continuous support to explore the mechanisms of vascular homeostasis and remodeling. As a result, the number of publications on vascular smooth muscle cells, atherosclerosis, and microRNA has significantly increased. Some important pioneering breakthroughs in basic translational research are attributed to the increased and targeted funding, for example, it was first reported by Chinese scientists that the coronary artery is derived from endocardium; muscle-specific mitsugumin 53 acts as a primary component of cardiac ischemic preconditioning and critically contributes to cardiac diabetic cardiomyopathy via regulating fatty acid metabolism; endothelial function is improved by dietary capsaicin through activating the transient receptor potential vanilloid; and consumption of spicy foods is related to a reduced risk of mortality because of ischemic heart diseases.

Furthermore, government funding contributes critically to promote the establishment of research platform and innovative as well as risk-taking research. Major research centers and key laboratories at national and local levels were established under the financial support of the government, with a goal

Nonstandard Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS</td>
<td>Chinese Academy of Science</td>
</tr>
<tr>
<td>CVD</td>
<td>cardiovascular disease</td>
</tr>
<tr>
<td>CVR</td>
<td>cardiovascular research</td>
</tr>
<tr>
<td>NSFC</td>
<td>National Natural Science Foundation of China</td>
</tr>
<tr>
<td>RMB</td>
<td>Ren Min Bi</td>
</tr>
</tbody>
</table>

Figure. Publications and grants from the National Natural Science Foundation of China (NSFC) during 2006 to 2015. (A and B) Number and contribution of publications and highly cited original research papers in the field of cardiovascular research in non–open-access journals by corresponding authors from China during 2006 to 2015 based on Web of Science Database Science Citation Index Expanded up to March 4, 2016. The data were provided by the Shanghai Information Center for Life Sciences of the CAS. (A) The number (red curve) and percentage (blue curve) of publications. (B) The number (red curve) and percentage (blue curve) of highly cited research papers (ranking among the 4372 of top 1% most cited papers out of 400,384 total ones in the field based on the Essential Science Indicators database up to September/October of 2015. (C) Grant number and (D) funding amount from NSFC for the cardiovascular research from 2006 to 2015. The data were provided by NSFC of China.
to develop CVR excellence. For example, in 2011, China’s National Center for Cardiovascular Diseases was established based in Fuwai Hospital, and in 2013, the government initiated 2 National Clinical Research Centers for CVR in Fuwai hospital and Anzhen hospital. In addition, the General Program of NSFC encourages researchers at various career stages to freely select topics in cardiovascular areas. During the past 10 years, among the total research-related program funding of NSFC in CVR, 83.78% was for the General Program. These incentives are important to help researchers to develop a more focused specific scheme with a high potential impact, translational and clinical values. For example, with the support of the General Program of NSFC, Li’s group\(^{12}\) revealed a novel function and regulatory mechanisms of interferon regulatory factor 8 in cardiac remodeling.

Although the rapid increase of government investment has brought a robust increase in the output of CVR, the funding is still not appropriately in line with the rapid development of the national Gross Domestic Product, growing aging population, and the urgent health needs of patients with CVD. To continue improvement of the quality and impact of Chinese cardiovascular science and promote translational research and precision therapy, a continuing increase of investment from government, including the central and local governmental agencies, in this area is imperative to ensure high-quality research with global impact. In addition, the financial support from nongovernment sources needs to be energetically developed. This needs to be supported and guided at least in part by the central or local governments to substantially increase private sector initiatives to develop innovative research programs and recruit and retain talents, by integrating government, clinical and private sector resources, and platforms.

**Researcher Roles**

Researchers are at the core of transition in the output of Chinese cardiovascular basic research. Many active Chinese researchers who obtained overseas study and work experience have returned to China during the past 20 years under the support of governmental and institute talent programs, such as One Hundred Talents Program initiated in 1994 by the CAS, Yangtse River Scholars Program by the Ministry of Education of China from 1998, and more recently, Thousand Young Talents Program launched in 2011 by the central government. Besides attracting the elite researchers from recognized universities and institutes globally, a critical issue is to develop and retain talented researchers. NSFC is playing a leading role in this aspect by launching specific Talent Program that targets researchers at various career stages, such as the Distinguished Young Scholars Program for well-established senior researchers, the Excellent Young Scholars Program for young researchers starting their own programs, and the Young Fund for young investigators just starting independent research. In 2006, NSFC funded only 53 cardiovascular researchers with 13.56 million RMB, whereas in 2015, it increased to 337 with 125.22 million RMB. The funding in 2015 was 9.23-fold of that in 2006 (Figure 1D). This major transition in the support for talents helps to foster and retain outstanding researchers in this field and especially benefits the development of young researchers. Until now, a total of 25 young scholars in the field of CVR were supported by NSFC for Distinguished Young Scholars Program. They all conducted creative researches and grew up as outstanding academic leaders in the forefront of clinical and basic research in CVR and made important contribution to the development of CVR in China.

Meanwhile, more highly motivated and talented MS and PhD students as well as young researchers are involved in CVR. As a result, the base of cardiovascular researchers in China significantly increased during the past 10 years, for example, membership in the China Section of the International Society for Heart Research increased from 289 in 2006 to 1140 in 2015 (provided by the China Section of International Society for Heart Research). However, the evolving base and capacity of Chinese cardiovascular researchers do not adequately meet the urgent need for reducing the CVD risk. The world-class academic leaders, as well as highly talented and experienced research leaders, need to be fostered. Moreover, a stronger funding support to postdoctoral scientists, and training for researchers, including principal investigators at all stages of careers, as well as the technicians, are needed. In addition, evaluations for faculty recruitment and scientific performance needs to involve broader assessment mechanisms to include research productivity–based global relevance as well as scientific quality rather than simply counting the publication number or impact factors as is currently practiced at most Chinese institutions. Furthermore, a more productive and efficient research environment needs to be fostered by increasing global competition.

**Cooperation Roles**

Increased domestic and international cooperation, founded by NSFC and Chinese Ministry of Science and Technology, is contributing importantly to the rapid growth of output and impact of CVR. For example, NSFC increased funding for the International Cooperation Program from 1.03 million RMB in 2006 to 8.81 million RMB in 2015 (Figure 1C and 1D) and funded 15 Key International Cooperation Programs of CVR in the field of epigenetics, metabolomics, and stem cells in the past 5 years. Although most of these are still underway, some encouraging progress has already been made. For example, the researcher from Peking University collaborated with the researcher from University of London and revealed a novel molecular mechanism of vascular injury and repair.\(^{13,14}\) The success of domestic and international collaborations is exemplified by the increased incidence of highly cited collaborative papers during the past decade: collaborative highly cited papers increased from 0% in 2006 to 70% in 2015 (data were provided by the Shanghai Information Center for Life Sciences of CAS based on the Essential Science Indicators database). However, it is still necessary to further strengthen the relationship with the top-tier universities and institute globally and promote deeper and tighter domestic and international collaborations by sharing knowledge, facilities, and resources including scientific data and animal models. One specific and practical initiative to promote this would be to remove the barrier of authorship contribution by reforming the assessment system from assigning credit for each article solely to author(s) with first institute into a more appropriate way to recognize the contributions of all authors.
In conclusion, the increased government investment in CVR during the past decade has supported a remarkable transition of Chinese cardiovascular basic research productivity that is characterized by a surge in the volume of publications but moderate relative improvement in overall quality. Global research impact still lags behind publication quantity. To deal with the rapidly expanding challenges of CVD, the research model as it applies to the Chinese situation needs to be further developed and fine-tuned. First, a clinically driven, basic, and translational research model should be developed and implemented. Second, more emphasis needs to be given to develop, expand, and validate Traditional Chinese Medicine especially as it applies to the prevention and treatment of CVD. Third, cross-discipline integration and collaboration need to be emphasized. To implement these changes and ensure growth, China needs to increase funding for CVR even more, expand the base of researchers, and improve research environments as well as support system to favor excellence and innovation. In addition, more CVR centers and key laboratories need to be established to promote integrative and collaborative CVR at the levels of basic, translational, and clinical studied and developmental pharmacology research. Communication and collaboration between basic scientists with physicians need to be closer and deeper; the government and institutes need to develop efficient mechanisms and platforms to promote the collaboration between basic scientists and physicians. These efforts will be essential to continue the growth of Chinese CVD research, align it with the overall economic growth, and develop new strategies that are so urgently needed to fight against the growing threat of CVD to the people of China.

Acknowledgments

We thank Hongbo Jiang, Hengzhe Wang, and Kaiyun Mao from the Shanghai Information Center for Life Sciences of the Chinese Academy of Science (CAS) for the analysis of publications and patents in the field of cardiovascular research.

Disclosures

None.

References


Key Words: analysis ■ China ■ intellectual property ■ research ■ science
Chinese Basic Cardiovascular Research in Transition
Xinyang Hu, Huang-Tian Yang, Yuangui Zhu, Jian'an Wang and Erdan Dong

Circ Res. 2016;118:1876-1879
doi: 10.1161/CIRCRESAHA.116.308063
Circulation Research is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2016 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7330. Online ISSN: 1524-4571

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circres.ahajournals.org/content/118/12/1876

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation Research can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation Research is online at:
http://circres.ahajournals.org/subscriptions/