Original article

Trend in Spanish cardiology research and global comparative analysis of major topics

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A B S T R A C T

Introduction and objectives: We used bibliometric techniques to analyze the participation of Spanish institutions in research on major cardiovascular topics during the last 4 decades.
Methods: Bibliometric indicators of production, collaboration and impact were obtained from the Science Citation Index Expanded (SCIE) database. Search strategies were used in major topics and institutional collaboration networks were identified, represented using the Kamada-Kawai algorithm.
Results: Global cardiovascular publications doubled from 2000 to 2018. In 2018, those by Spanish authors represented 2.33%, with a participation of between 7% and 1.84%, depending on the topics analyzed. The offset with respect to global production was between 0 and 7 years. Annual growth rates were higher in more recent topics. *Revista Española de Cardiología* published the largest number of articles from Spanish institutions. The journals generating the highest number of citations in the chosen topics were the *Journal of the American College of Cardiology*, *Europace*, and the *European Heart Journal*. Analysis of collaboration revealed a close interrelation between Spanish and foreign institutions, as well as groups with high production publishing independently.
Conclusions: The analysis disaggregated by subject showed the sustained growth of Spanish cardiovascular scientific production and more rapid growth in recently appearing topics. Collaboration networks showed a high degree of interrelation between Spanish and foreign institutions, including hospitals, universities, research institutes, and scientific societies.

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Evolución de la investigación cardiológica española y análisis comparativo mundial de temas de especial relevancia

R E S U M E N

Introducción y objetivos: Se utilizan técnicas bibliométricas para analizar la participación de instituciones españolas en la investigación sobre temas relevantes en el ámbito cardiovascular durante las últimas 4 décadas.
Métodos: Se obtienen indicadores bibliométricos de producción, colaboración e impacto a partir de la base de datos *Science Citation Index Expanded* (SCIE). Se utilizan estrategias de búsqueda en temas relevantes y se identifican las redes de colaboración institucional, que se representan utilizando el algoritmo de Kamada-Kawai.
Resultados: Las publicaciones cardiovasculares en el mundo se han duplicado entre 2000 y 2018. Actualmente, las de autores españoles representan el 2,33%, con una participación entre el 7 y el 1,84%, según los temas considerados. El desfase respecto a la producción mundial está entre 0 y 7 años. Las tasas de crecimiento anual son mayores en los temas analizados de aparición más reciente. *Revista Española de Cardiología* ha publicado el mayor número de artículos de instituciones españolas. Las revistas que han generado mayor número de citas en los temas elegidos son *Journal of American College of Cardiology, Europace* y *European Heart Journal*. El análisis de la colaboración revela una gran interrelación entre instituciones españolas y extranjeras, así como grupos con gran producción que publican de manera autónoma.

Conclusiones: El análisis desagregado por temas muestra que el crecimiento de la producción científica cardiovascular española es constante, con mayores tasas de incremento en los temas más recientes. Las redes de colaboración muestran un alto grado de interrelación entre instituciones españolas y extranjeras, que abarca centros hospitalarios, universidades, institutos de investigación y sociedades científicas.

Abbreviations

CRT: cardiac resynchronization therapy
DES: drug eluting stents
miRNA: micro-RNA
NOAC: nonvitamin K antagonist oral anticoagulant
SCIE: Science Citation Index Expanded
S/V: sacubitril/valsartan
TAVI: transcatheter aortic valve implantation

INTRODUCTION

Cardiovascular diseases are the main cause of mortality in the European Union and, of these, ischemic heart disease is the most common.[1] In recent decades, there has been a decreasing trend in cardiovascular mortality.[2] However, this trend has slowed because of circumstances such as the increased prevalence of obesity and diabetes, the persistence of the smoking habit, changes in eating habits, increased sedentary lifestyles, and inequalities between countries or social groups.[3–5] The persistence of high morbidity and mortality underscores the need for further progress in understanding the causes and physiopathological processes involved, and in translating this understanding into prevention, diagnosis, and treatment.[6]

Scientific research and social improvements have had a positive impact on its control.[7] Nevertheless, the information available should be widened and disseminated, and health care providers should become more involved in research. Bibliometric studies help to clarify the state of scientific activity in different areas not only at the global level, but also by country or group.[8–17] Spanish cardiovascular scientific production has been analyzed over recent decades.[9–16] Despite quantitative and qualitative advances, limitations and weaknesses remain. Innovation is reflected both in the development of new approaches to the study and control of cardiovascular diseases and in new procedures, devices, and treatments that expand the possibilities of diagnosing and treating them. Progress in research and interest in its application to clinical practice is demonstrated by the growing participation of researchers contributing to increasing scientific production related to these topics and to their dissemination, assessment, and application.

The present study used bibliometric techniques to analyze the participation of Spanish institutions in research on specific and relevant topics related to cardiovascular diseases over the last 4 decades. It is based on the hypothesis that differences between the beginnings of scientific articles on a given topic, the characteristics of subsequent variations in scientific production, and their interrelationships over time reflect the interest raised by these articles among researchers in specific countries, as well as their degree of dissemination and influence.

METHODS

We conducted a literature search using the Science Citation Index Expanded (SCIE) database of the Web of Science Core Collection owned by Clarivate Analytics. During July 2019, we extracted records up to and including 2018 as well as information on the type of document ("article", "review", "letter" and "editorial").

We first conducted a general search using a procedure employed in previous studies[9,10]:

- Phase 1: We selected all articles included in the Cardiac & Cardiovascular System category in *Journal Citation Reports* (JCR) and identified those which contained at least 1 Spanish institution in the authors' affiliations.
- Phase 2: We identified cardiological scientific production in journals addressing other areas, such as general medicine, internal medicine, diagnostic imaging, pediatrics, and nephrology, as well as multidisciplinary journals. For this purpose, we identified all the names of cardiological units, services, or departments and searched the institutional affiliation field (address or place of work), in this case without setting any limitations regarding the journal in which the article was found. To retrieve cardiology units with Spanish affiliations, the term "spain" was also included in the terms and combined with the Boolean operator "SAME". The following strategy was used: AD = (Arrhytmia OR Arritmi* OR Cardio* OR Cardia* OR Corazon OR Coronar* OR Echocardio* OR Ecocardio* OR Heart OR Kardi* OR Marcapaso* OR Hypertens* OR Hipertens* OR Ipertens* OR Arterios*) SAME spain.
- Phase 3: A new query was conducted to retrieve records not included in source journals in the Cardiac & Cardiovascular Systems category or not signed by authors affiliated with a cardiology unit, service, or department. This query took the form of searching for records that included the terms used in the title field in the previous query. However, we eliminated this particular search in the "topic" field because of the amount of "noise" generated when searching the abstracts. The term "Spain" was also included in the institutional affiliation field (AD = Spain).
- Phase 4: After retrieving the cardiological articles, we created a list of those that had received the most citations over the last 4 decades and selected 8 topics introduced for the first time in the field of cardiovascular disease during this period. The following selection criteria were applied: *a)* the topic and the terms defining it appeared at an identifiable and defined moment in time during the last 4 decades (eg, "TAVI" begins to appear in the global literature in 2001); *b)* the topic was among the 200 most cited topics in the decade corresponding to its appearance as an indicator of interest within the scientific community; *c)* the articles addressed a variety of participants in the field of cardiovascular disease with the aim of covering aspects included in areas such as ischemic cardiopathy, arrhythmias, heart failure, valvulopathies, physiopathology, or pharmacological treatment. The following topics were selected: catheter ablation, cardiac resynchronization therapy (CRT), drug-eluting stent (DES), takotsubo syndrome, transcatheter aortic valve implantation (TAVI), nonvitamin K antagonist oral anticoagulant (NOAC), micro-RNA (miRNA), and sacubitril/valsartan (S/V).

For each topic, the global results were combined using the chosen strategy: subsequently, the analyses were limited to articles in which researchers from Spanish centers had participated.

The search strategies applied to each topic (table 1) were obtained by setting the topic field (TS) to retrieve the terms in one of the following fields: title, summary, or keywords.

We then analyzed the bibliometric indicators of production, collaboration, and impact, and identified the first articles published on each of these topics in international and Spanish journals. We standardized variations in the names of the authors and institutions described in the articles. We also standardized author keywords, grouped singular and plurals, synonyms, and syntactic variants, and spelled out acronyms. These procedures allowed us to identify institutional collaboration networks and keyword networks (generated by analyzing the co-occurrence of keywords in the articles). They were visually represented using the Kamada-Kawai algorithm implemented in the Pajek network analysis and visualization software.[18] In collaboration networks, institutions are represented as nodes or vertices, whose size depends on their production. Taking into account the density of the represented data, nodes were joined by lines if the number of collaborations was higher than a threshold established in each figure, because low thresholds lead to a large number of connections that hinder correct visualization. Regardless of the aforementioned threshold, information obtained on the degree of collaboration between institutions is available in table 1 of the supplementary data. Data used to represent the co-occurrence of keywords is available in table 2 of the supplementary data. Keywords assigned by the authors of the articles were used to identify the co-occurrence of the same words in the documents analyzed.

Statistical analysis

The averages of the quantitative variables were compared using the Student t test (normal distribution) or the Mann-Whitney U statistic. A P value of $< .05$ was used as a cutoff for statistical significance. The relationship between the number of articles and the years elapsed was quantified using the logarithmic transformation of the exponential model (IBM-SPSS v. 23.0 software package).

RESULTS

Figure 1 shows the temporal evolution of the number of global cardiovascular articles identified using the SCIE data for 1900 to 2018. Global cardiovascular publications have more than doubled since the beginning of the 21st century, increasing from 32 042 in
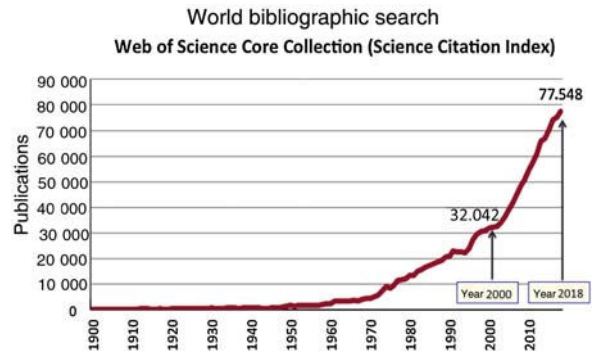

Figure 1. Temporal evolution of the number of global cardiovascular articles identified using the chosen search strategy.

2000 to 77 548 in 2018. Between 1900 and 2018, the SCIE included 1 572 747 cardiological articles, of which 36 584 were produced by Spanish institutions (2.33%). This proportion was 1.3% in 1990, 2.5% in 2000, 3.2% in 2010, and 3.5% in 2018.

Scientific production in the chosen topics

Table 2 shows the number of global and Spanish cardiovascular articles, the ratio of Spanish to global articles as percentages, and number of years between the first global cardiovascular articles and the first Spanish ones (lag). Production on the topic "S/V" was relatively low in absolute numbers. This is because articles on this topic only began to be published recently: nevertheless, Spanish researchers participated in 7% of the overall production. Spanish production related to the other topics ranged between 3% and 4% of the total, with the exception of the topic "miRNA" (1.84%).

There was a lag of 4 years to 7 years between the year of publication of the first articles related to each topic by international and Spanish researchers. The only exception to this trend was related to the topic "S/V", because the initial global and Spanish articles were published within the same periods.

In each case, different periods of time have elapsed since the appearance of the first Spanish articles on a given topic until 2018. For example, the maximum time elapsed was 30 years in the case of "catheter ablation" and the minimum was 9 years in the case of "S/V". We calculated the quotient of the number of articles by the years elapsed since the appearance of first articles. The highest

Table 1

Search strategies used in each of the chosen topics

Topics	Search strategy
Catheter ablation	TS = ("*catheter ablation*" or "transcatheter ablation")
Cardiac resynchronization therapy (CRT)	TS = (resynchronization or resynchronization or resinchronization or "biventricular pac*" or "biventricular stimulation" or "biatrial pac*" or "cardiac dyssynchron*")
Drug-eluting stent (DES)	"Elut* stent*"
Nonvitamin K antagonist oral anticoagulant (NOAC)	TS = (Apixaban or Dabigatran or Edoxaban or Rivaroxaban or "Direct* oral* anticoagulant*" or "Direct Xa inhibitor*" or "Factor* Xa inhibitor*" or "Nonvitamin K antagonist* oral anticoagulant*" or "Nonvitamin K oral anticoagulant*" or "Novel anticoagulant* agent*" or "Novel oral anticoagulant*" or "New oral anticoagulant*" or "Nonvitamin K-dependent oral anticoagulant*" or "Non-VKA oral anticoagulant*" or "Nonvitamin K antagonist* OAC")
Sacubitril/valsartan (S/V)	TS = (ARNI or ARNIs or Neprilysin or Sacubitril or LCZ696 or "LCZ 696")
Tako-tsubo syndrome	TS = (Tako-tsubo or "Tako-tsubo" or "Stress cardiomyopa*")
Transcatheter Aortic Valve Implantation (TAVI)	TS = ("Percutaneous aortic prosthesis" OR "Percutaneous aortic valve* replacement" OR "TAVI" OR "TAVR" OR "Transcatheter aortic valve*" OR "Transcatheter aortic valve*" OR "Transcatheter heart valve*" OR "Transcatheter heart valve*" OR "Transcatheter valve* replacement" OR "Transcatheter valve* replacement" OR "Transfemoral aortic valve*")
micro-RNA (miRNA)	TS = (micro-RNA* or "Micro RNA*" or miRNA*)

Table 2
Number of global and Spanish cardiovascular articles, percentages, and number of years between the first global articles and the first Spanish ones (lag)

Topics	World	Spain	% Spain/World	World/Spain lag
Transcatheter aortic valve implantation	7297	297	4.07%	2001-2008, 7 y
Cardiac resynchronization therapy	9975	361	3.62%	1995-2000, 5 y
Nonvitamin K antagonist oral anticoagulant	4344	155	3.57%	2005-2009, 4 y
Sacubitril/valsartan	727	51	7.02%	2010, 0 y
Tako-tsubo syndrome	3376	101	2.99%	2000-2004, 4 y
Drug-eluting stent	13 777	558	4.05%	1996-2003, 7 y
Catheter ablation	16 522	594	3.60%	1983-1989, 6 y
micro-RNA	7551	139	1.84%	2005-2009, 4 y

value obtained was for the topic "DES" (34.9), followed by "TAVI" (27) and "catheter ablation" (19.8). The lowest value obtained was for the topic "S/V" (5.7).

Figure 2 shows the evolution over time of Spanish articles on the 8 chosen topics. The highest averages of the annual growth rate were obtained for the topics "S/V" (131.8%), "miRNA" (124.8%), "NOAC" (66.1%), and "TAVI" (63.1%). These topics were the most recent and had a higher average (96.4 ± 36.9) than that of the 4 oldest topics (6.2 ± 7.2; $P < .01$). We also compared the slope of the logarithmic transformations of the exponential models obtained by calculating the quotient of the number of articles by years elapsed. The average of the most recent topics (0.33 ± 0.05) was higher than that of the oldest ones (0.12 ± 0.02; $P < .0001$).

Table 3 shows the number of citations and the citation/article quotient by topic. In absolute values, the highest values were obtained for "DES" and "catheter ablation" and the lowest ones for "S/V". These values were normalized by dividing them by the number of articles: the highest values were obtained for "miRNA" and "DES" and the lowest ones for "tako-tsubo".

We also calculated the quotient of the number of citations by years elapsed since the first articles: the highest values were obtained for "DES" (993), followed by "TAVI" (556) and "catheter ablation" (465). The lowest value (79) was obtained for "tako-tsubo".

Table 4 shows the journals with the most Spanish articles on each topic, the journals that have generated the most citations of these articles, and the journals with the highest citation/publication quotients. *Revista Española de Cardiología* published the most articles on 5 of the topics, the *Journal of the American College of Cardiology*, *Europace*, and *European Heart Journal* generated the most citations, and *Nature*, the *New England Journal of Medicine*, and *The Lancet* had the highest quotient of citations/articles. The number of citations generated in *Europace* was mainly due to the topics "CRT" and "catheter ablation".

Thematic and institutional collaboration networks

The thematic co-occurrence networks were obtained using the records of the available keywords. Table 3 shows the number of records containing keywords and their percentage in relation to the total number of records by topic. Figure 3 shows the keyword networks for the topics "DES" and "TAVI". The "DES" network shows, for example, relationships with percutaneous interventions and the clinical manifestations of ischemic cardiopathy, and interconnections with stent thrombosis, restenosis, diabetes mellitus, optical coherence tomography, or intravascular ultrasound. The "TAVI" network shows relationships with aspects such as pacemaker, left bundle branch block, 3D echocardiography, stroke, aortic or mitral regurgitation, endocarditis, or prognosis. Figure 4 shows the keyword networks for the topics "NOAC" and "catheter ablation". The "NOAC" network shows, for example, the central relationship with atrial fibrillation, stroke, and stroke prevention, and with renal function, rhythm control, and bleeding. The "catheter ablation" network shows aspects such as the strong interrelationship with atrial fibrillation and relationships with different types of arrhythmias, stroke, anticoagulation, antiarrhythmic drugs, magnetic resonance imaging, and implantable defibrillator.

Figure 5, figure 6, and figure 7 show the institutional collaboration networks with articles on "catheter ablation", "DES", "CRT", "TAVI", "NOAC", and "miRNA". For all topics, there are very large networks with strong interrelationships between Spanish and foreign institutions, as well as networks in which a smaller number of institutions participate. Almost all of the networks show collaboration between health and university institutions. The networks also show the participation of research institutes and, in specific cases, scientific societies and public institutions dedicated to research. Thus, there are many interrelationships between specific hospitals and universities. The Spanish Society of Cardiology appears in the "CRT" network, research institutes (eg, IDIBAPS, INCLIVA) appear in the "CRT", "catheter ablation" "DES", and "S/V" networks, the Spanish National Research Council (CSIC) appears in the "miRNA" network, the Instituto de Salud Carlos III appears in the "miRNA" and "S/V" networks, and the Centro de Investigación Biomédica en Red (CIBER) appears in the "S/V" network. We set a minimum threshold of collaborations with a given center by topic to facilitate their
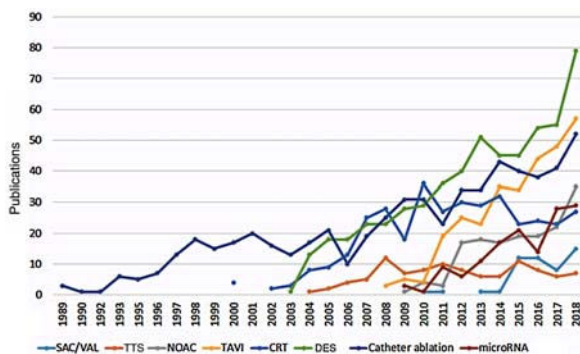

Figure 2. Temporal evolution of articles on the chosen topics by authors from Spanish institutions. CRT, cardiac resynchronization therapy; DES, drug-eluting stents; NOAC, nonvitamin K antagonist oral anticoagulation; SAC/VAL, sacubitril/valsartan; TTS, tako-tsubo syndrome; TAVI, transcatheter aortic valve implantation.

Table 3

Number of bibliographic citations generated by authors from Spanish institutions and number of citations per article corresponding to each chosen topic. The table shows the number of articles in which the keywords were included and their percentage in relation to the total

Topics	Citations, n	Citations/records	Records with keywords, n	Records with keywords, %
Transcatheter aortic valve implantation	6116	20.6	200	67.34
Cardiac resynchronization therapy	5717	15.8	267	73.96
Nonvitamin K antagonist oral anticoagulant	3701	23.9	94	60.65
Sacubitril/valsartan	943	18.5	37	72.55
Tako-tsubo syndrome	1185	11.7	57	56.44
Drug-eluting stent	15 888	28.5	392	70.25
Catheter ablation	13 953	23.5	473	79.63
micro-RNA	4365	31.4	88	63.31

Table 4

Journal with the highest number of articles (values in parentheses), the most bibliographic citations (values in parentheses), and the highest citation/article quotient (values in parentheses) in relation to each chosen topic

Topics	Journal with the most articles	Journal generating the most citations	Journal with the highest citation/article quotient
Transcatheter aortic valve implantation	*Revista Española de Cardiología* (64)	*European Heart Journal* (1127)	*European Heart Journal* (93.9)
Cardiac resinchronization therapy	*Revista Española de Cardiología* (105)	*Europace* (795)	*New England Journal of Medicine* (244.0)
Nonvitamin K antagonist oral anticoagulant	*Revista Española de Cardiología* (23)	*New England Journal of Medicine* (615)	*New England Journal of Medicine* (615.0)
Sacubitril/valsartan	*International Journal of Cardiology* (6)	*Circulation* (277)	*The Lancet* (266.0)
Tako-tsubo syndrome	*International Journal of Cardiology* (19)	*Revista Española de Cardiología* (233)	*Journal of Biological Chemistry* (102.0)
Drug-eluting stent	*Revista Española de Cardiología* (85)	*Journal of American College of Cardiology* (3702)	*New England Journal of Medicine* (381.6)
Catheter ablation	*Revista Española de Cardiología* (143)	*Europace* (2997)	*British Journal of Radiology* (138.0)
micro-RNA	*Plos One* (7)	*Nature* (788)	*Nature* (788.0)

graphic representation, although this approach implies that institutions with collaborations below this threshold were not represented. All the information collected on production and collaborations between centers and institutions, including the Spanish National Center for Cardiovascular Research and the Centro de Investigación Biomédica en Red, is available in table 1 of the supplementary data.

DISCUSSION

Bibliometric indicators provide information on the activity conducted in a field of research, which direction it is headed, the level of interest in the topic in groups working in certain areas, and the degree of interrelationship between centers, countries, or researchers.[17,19,20] Such activity has been analyzed in the field of cardiovascular diseases across the world and by country.[20,21] Studies have shown a constant increase in scientific production during the first decade of the 21st century[21,22] as well as differences according to socioeconomic level.[21,23–25]

Previous studies have analyzed Spanish cardiovascular publications for the periods 1990 to 1996[14] and 2003 to 2007.[9,10] In the former period, there was slightly lower growth than that in the area of biomedicine, but there was increased growth in international collaborations. In the latter period, Spanish cardiovascular scientific production placed sixth in the European Union and ninth in the world or tenth when taking into account journals in the first quartile. We recommended that research should be supported and promoted to maintain adequate levels of scientific production.

A later study[11] analyzed the impact of the scholarships and research grants awarded by the Spanish Society of Cardiology during the period 2000 to 2006. It was found that the average number of articles supported by grant was 1.12. A similar analysis was recently conducted for the period 2007 to 2012, finding that 122 articles resulted from 88 projects.[26] A previous study analyzed the proportion of scientific articles resulting from articles accepted at congresses of the Spanish Society of Cardiology in 2002, 2005, and 2008.[12] It was found that 38.33% led to subsequent articles, the most in *Revista Española de Cardiología* (37.41%), followed by the *European Heart Journal* (5.44%).

The present study shows that there has been constant growth in global cardiovascular scientific production, which has been matched by Spanish cardiovascular scientific production in recent decades. The selection of specific topics facilitated the analysis of aspects related to their emergence and the participation of Spanish institutions. With the exception of the topic "S/V", we found that in relation to the topics studied there was a lag of between 4 years and 7 years in Spanish cardiovascular scientific production compared with that of the rest of the world, although annual growth rates were higher in articles related to more recent topics.

The Research and Innovation Observatory (*2017 RIO Country Report*) of the European Commission placed Spain in a moderate position in innovation and suggested actions that would have a positive impact, such as the introduction of improvements in the employment conditions of researchers, the funding and management of research systems, and the involvement of companies. The percentage of the gross domestic product allocated to R + D in Spain was less than the European Union average and the number of

Figure 3. Thematic networks based on the keywords of articles by authors from Spanish institutions. A: Topic "DES". B: Topic "TAVI". The size of the nodes represents the degree of participation of a keyword, while the width of the connections indicates the strength of the relationship, accompanied by the value (number of times a keyword in an article coincides with those in another). DES, drug-eluting stents; TAVI, transcatheter aortic valve implantation. gr3.
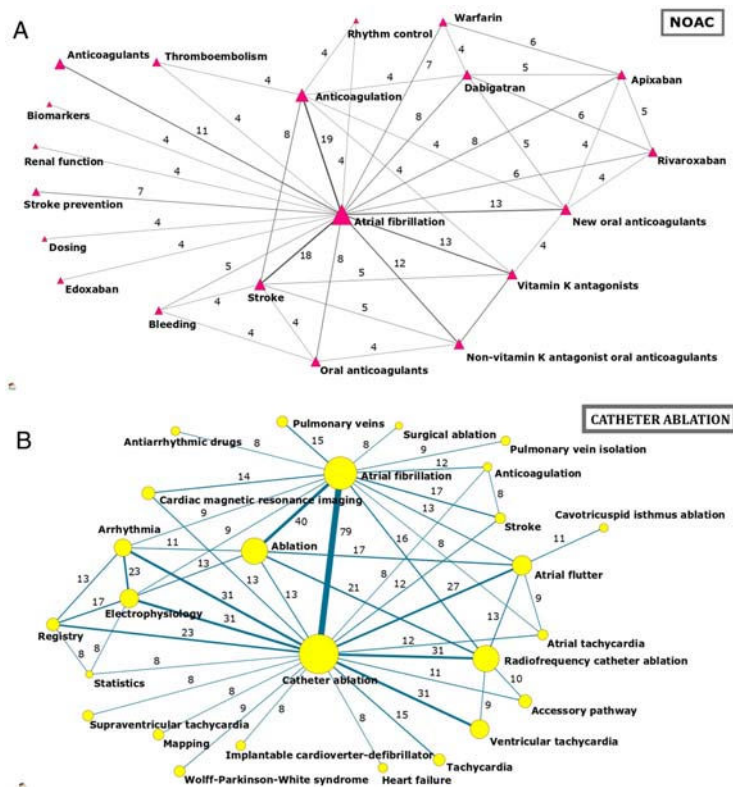

Figure 4. Thematic networks based on the keywords of articles by authors from Spanish institutions. A: Topic "NOAC". B: Topic "catheter ablation". NOAC, nonvitamin K antagonist oral anticoagulation.
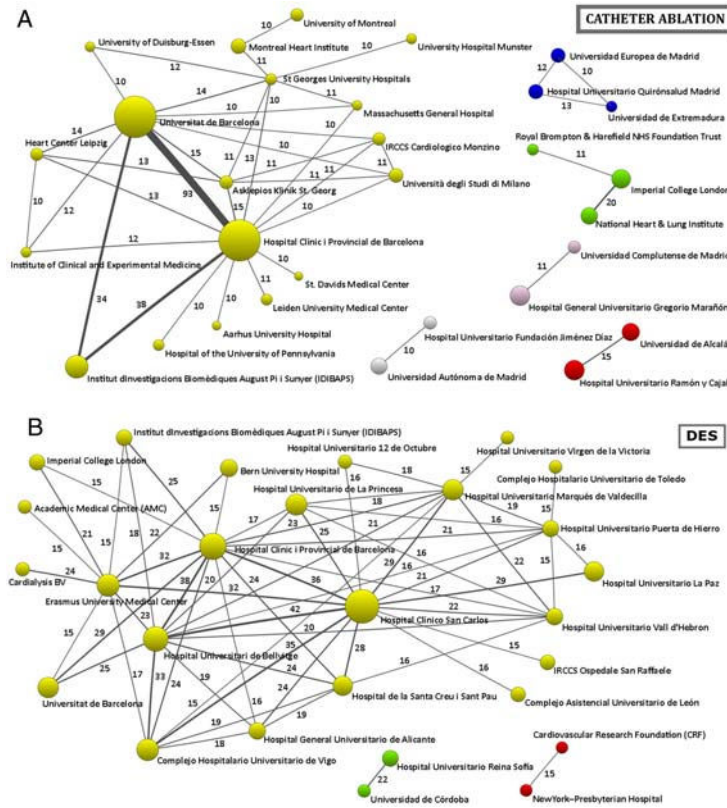
Figure 5. Institutional collaboration networks based on articles by authors from Spanish institutions. A: Topic "catheter ablation" (minimum threshold of 10 collaborations with the same center). B: Topic "DES" (minimum threshold of 15 collaborations). The size of the nodes represents the production of an institution, while the width of the connections indicates the degree of collaboration between 2 nodes, accompanied by the value (number of times they have published together). DES, drug-eluting stents.
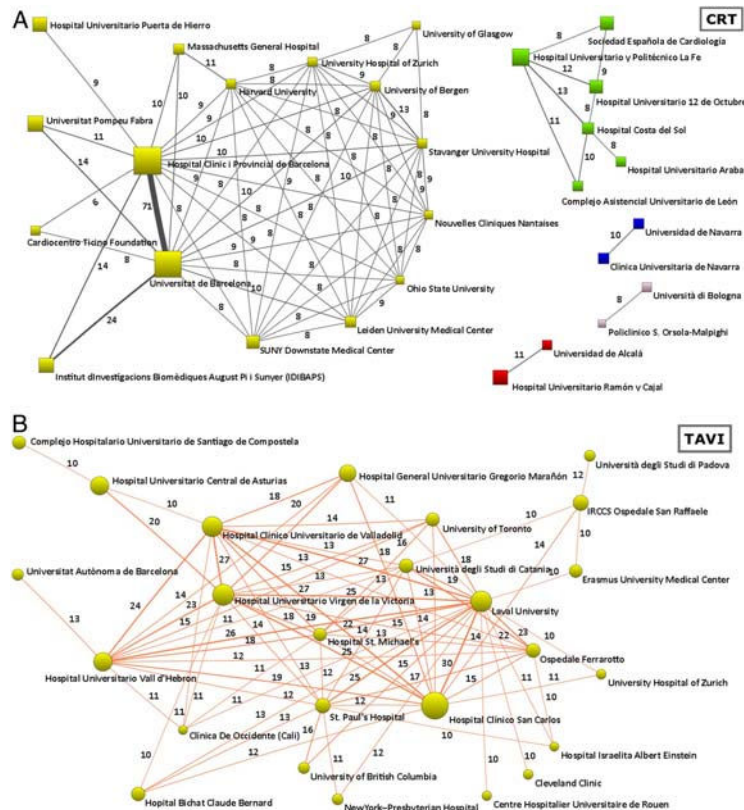

Figure 6. Institutional collaboration networks. A: Topic "CRT" (minimum threshold of 8 collaborations). B: Topic "TAVI" (threshold of 10 collaborations). CRT, cardiac resynchronization therapy; TAVI, transcatheter aortic valve implantation.
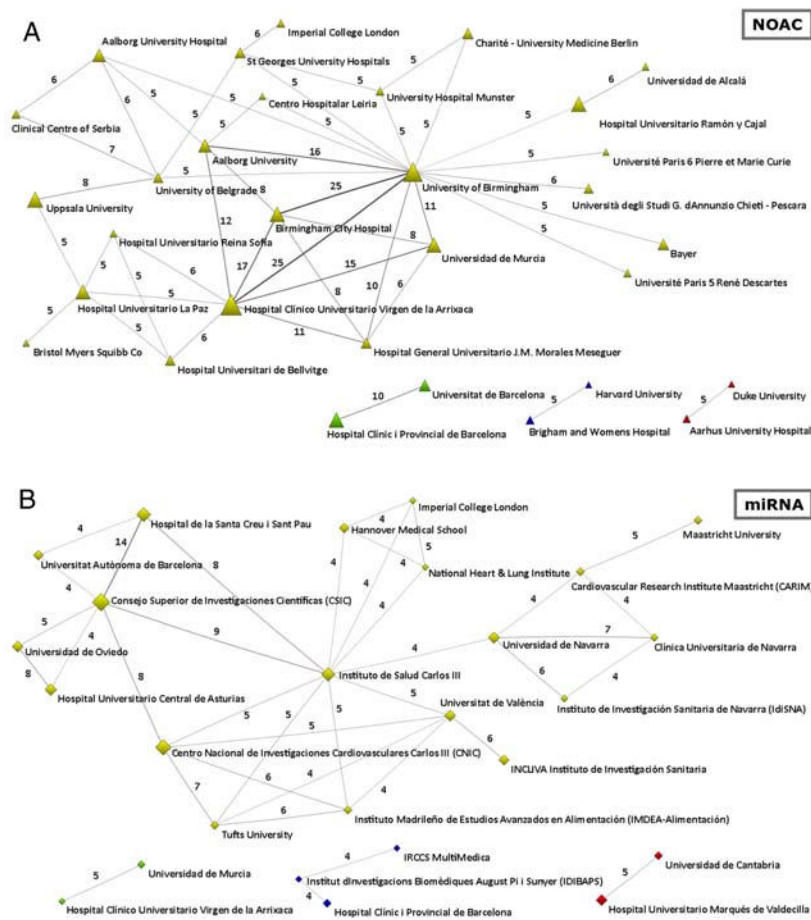
Figure 7. Institutional collaboration networks. A: Topic "NOAC" (minimum threshold of 5 collaborations). B: Topic "miRNA" (threshold of 4 collaborations). miRNA, micro-RNA; NOAC, nonvitamin K antagonist oral anticoagulation.

Table 5
Expenditure on R + D or on health, expressed as a percentage of the gross domestic product (GDP), and the number of researchers working on R + D in a selection of European and other countries

Country	Expenditure on R + D, % of GDP	Researchers dedicated to R + D per million population	Public spending on health, % of GDP
Germany	3.09 (2018)	5003 (2017)	9.91 (2019)
Spain	1.24 (2018)	2855 (2017)	6.37 (2019)
France	2.20 (2018)	4450 (2017)	9.37 (2019)
Greece	1.18 (2018)	3329 (2017)	4.62 (2019)
Ireland	1.15 (2018)	4115 (2017)	5.08 (2019)
Italy	1.40 (2018)	2245 (2017)	6.42 (2019)
Netherlands	2.16 (2018)	5011 (2017)	8.24 (2019)
Poland	1.21 (2018)	2543 (2017)	4.55 (2019)
Portugal	1.37 (2018)	4308 (2017)	5.86 (2019)
United Kingdom	1.72 (2018)	4341 (2017)	7.98 (2019)
Sweden	3.34 (2018)	7597 (2017)	9.27 (2019)
Switzerland	3.37 (2017)	5272 (2017)	7.83 (2019)
European Union[*]	2.18 (2018)	3731 (2017)	—
Canada	1.57 (2018)	4264 (2016)	7.60 (2019)
China	2.19 (2018)	1225 (2017)	2.86 (2017)
United States	2.84 (2018)	4245 (2016)	14.38 (2019)
Japan	3.26 (2018)	5304 (2017)	9.32 (2019)

The values in parentheses correspond to the year in which the data were obtained. Sources: World Bank Network[27] and Datos macro.expansión.[28]
[*] Group of countries comprising the European Union.

Spanish researchers per million population was also very low in EU and global rankings (table 5).

On average, more articles addressed the topics "DES", "TAVI", and "catheter ablation" than other topics per year, the main contributor being *Revista Española de Cardiología*. Most of the citations generated by Spanish authors were associated with "DES" and "catheter ablation". Nevertheless, less productive topics such as "miRNA" garnered a large number of citations per article. The journals generating the highest number of citations in the chosen topics were the those with a high impact factor, such as the *Journal of American College of Cardiology* or the *European Heart Journal*.

The analysis by thematic network showed that the chosen topics were directly related to aspects such as complications, the usefulness of complementary diagnostic procedures, and the assessment of results. The analysis of collaboration networks showed close interrelationships between Spanish and many foreign institutions and very extensive coverage of specific topics. These interrelationships included institutions such as hospitals, universities, research institutes, and scientific societies. The participation of the *Centro de Investigación Biomédica en Red* remains low because it is a relatively new body.

Limitations

The study was conducted using articles included in the SCIE database of the Web of Science. Thus, only the journals indexed in this database were taken into account, although we could have used others, such as Scopus. Nevertheless, SCIE is one of the most used databases, because it includes the citations and the journal impact factor, which is an indicator that cannot be obtained from other sources.

The analysis of chosen topics from specific periods does not replace a more generic analysis, but provides additional information. Topics were chosen according to the procedure described in the methodology section. This approach did not attempt to address all areas of cardiovascular disease and has the following limitations: *a)* the methodology used provides partial information on scientific production, because it mainly addresses new topics and highlights the results concerning technical topics and new drugs rather than other classic topics or more physiopathological aspects of cardiovascular disease; *b)* for these reasons, this partial information should be used to generate hypotheses and to supplement other available studies that provide more global information on scientific production; and *c)* in relation to cardiovascular scientific production, this study did not take into account Spanish GDP or the percentage of the GDP dedicated to research and health.

CONCLUSIONS

The analysis disaggregated by topic showed the sustained growth of Spanish cardiovascular scientific production and more rapid annual growth in recently appearing topics. Collaboration networks showed a high degree of interrelationships between Spanish and foreign institutions, including hospitals, universities, research institutes, and scientific societies.

CONFLICT OF INTEREST

None declared.

WHAT IS KNOWN ABOUT THE TOPIC?

- Previous analyses of cardiovascular scientific production by Spanish institutions have shown increases in global production and growing trends toward international collaboration. There are few studies on research on specific and relevant topics in the cardiovascular field.

WHAT DOES THIS STUDY ADD?

- The analysis disaggregated by topic showed the sustained growth of Spanish cardiovascular scientific production and more rapid annual growth in recently appearing topics. Collaboration networks showed a high degree of interrelationships between Spanish and foreign institutions, including hospitals, universities, research institutes, and scientific societies.

APPENDIX. SUPPLEMENTARY DATA

Supplementary data associated with this article can be found in the online version available at https://doi.org/10.1016/j.rec.2020.12.001

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