Coauthorship Networks and Institutional Collaboration in *Revista Española de Cardiología* Publications

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Introduction and objectives. The aim of this study was to analyze the patterns of investigator and institutional collaboration in papers published in the *Revista Española de Cardiología*.

Methods. Details of coauthorship and institutional collaboration involved in articles published in the *Revista Española de Cardiología* in the period 2000-2005 were recorded and a collaboration index was derived. Collaboration networks were identified using the TextToPajek and PAJEK software tools.

Results. Of the 980 papers analyzed, 95.1% had been authored by two or more individuals and 51.43% involved institutional collaboration. The overall collaboration index was 6.23 (standard deviation [SD] 3.1). There was a significant statistical relationship ($P<.02$) between the collaboration index and the journal section in which the article was published: the Original Articles and Special Reports sections had the highest collaboration indices (mean, 7.87 [2.88]; and mean, 6.59 [5.02], respectively). The 44 authors who had the highest publication rates were identified. In addition, 25 coauthorship networks involving 112 investigators were observed.

Conclusions. An analysis of collaboration networks led to the identification of a number of author networks in cardiovascular medicine in Spain, and highlighted the interrelationships between them in terms of both scientific research and scientific publications. The most significant aspect of institutional collaboration was the predominance of collaboration within institutions and within Spanish autonomous regions (ie, 80.57% of collaborations). Possible topics for future study include an analysis of the scientific productivity of the networks identified and of changes in the pattern of collaboration over time.

Key words: *Scientific publications. Coauthorship analysis. Institutional collaboration. Collaboration networks.*

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Redes de coautorías y colaboración institucional en Revista Española de Cardiología

Introducción y objetivos. El presente estudio analiza los patrones de colaboración de los investigadores y las instituciones en los trabajos publicados en REVISTA ESPAÑOLA DE CARDIOLOGÍA.

Métodos. Se identificaron las coautorías y relaciones de colaboración institucional de REVISTA ESPAÑOLA DE CARDIOLOGÍA en el período 2000-2005 y se obtuvo el índice de firmas/trabajo. Para construir las redes de colaboración se utilizaron los programas «TextToPajek» y «PAJEK».

Resultados. Se analizaron 980 trabajos, el 95,1% firmado en coautoría por 2 o más autores y el 51,43% en colaboración institucional. El índice de firmas/trabajo ha sido de 6,23 ± 3,1. Se encontró una relación estadística ($p < 0,02$) entre el índice de firmas/trabajo y la sección donde era publicado el trabajo, ya que los publicados en las secciones Artículos originales y Artículos especiales tenían un mayor índice de firmas/trabajo (media de 7,87 ± 2,88 y 6,59 ± 5,02, respectivamente). Se han identificado 44 autores de elevada productividad y 25 agrupaciones de autores integrados por 112 investigadores.

Conclusiones. El análisis de las redes de colaboración ha permitido identificar numerosas agrupaciones de autores del área cardiovascular en España, así como las relaciones existentes entre ellas desde el punto de vista de la investigación y las publicaciones científicas. El aspecto más significativo de la colaboración institucional fue el predominio de la colaboración intrainstitucional e intraautonómica (el 80,57% de las colaboraciones). Posibles estudios futuros podrían incluir el análisis de la producción científica de los investigadores de las agrupaciones identificadas y la evolución en el tiempo de los patrones de colaboración.

Palabras clave. *Publicaciones científicas. Análisis de coautorías. Colaboración institucional. Redes de colaboración.*

INTRODUCTION

Spanish scientific production in cardiovascular medicine has grown substantially in recent years. For the period 1994-1999, we identified 840 documents authored by Spanish researchers in the CD-ROM databases of the Institute for Scientific Information. Annual production rose by 80.9% between 1994 and 1999,[1] whereas the number of documents recorded in the National Science Indicators and National Citation Reports for 1994-2002 rose to 2556, with a constant increase in papers per year, growing from 6616 in 1994 to 9143 in 2002.[2] The Spanish journals that included greater numbers of articles in cardiovascular medicine were *Revista Española de Cardiología* (n=899) and *Medicina Clínica* (n=140)[2]. They were the two Spanish-language clinical journals that obtained the highest impact factors (IF) in the *Journal Citation Reports* of 2004 (IF=1.802 and IF=1.005, respectively) and first and third highest in 2005 (IF=1.769 and IF=1.074, respectively).[3] They also occupied first and second place in the Potential Impact Factor of Spanish Medical Journals study for 2003 (IF=1.501 and IF=1.061, respectively).[4]

In cardiology and biomedical research in general, collaborative production of papers has increased progressively. Collaboration is necessary to advance knowledge because research problems require multidisciplinary approaches[5] and because collaborative endeavors compensate for local weaknesses.[6] In cardiology research, professionals collaborate fundamentally in cardiology, family medicine and internal medicine, but biologists, chemists, pharmacists, mathematicians, and radiologists are also involved.[6,7]

In this context, the Spanish government's national plan for scientific research, development and technological innovation (Plan Nacional de I+D+I) for 2004-2007[8] attempts to promote multidisciplinary research. In biomedicine, the call for thematic priorities of cooperative research (RETIC) by Madrid's Instituto de Salud Carlos III[9] aims to contribute to constructing a scientific base for the programs and policies of the Spanish national health service in the areas prioritized in the aforementioned national plan through linking up multidisciplinary and multiinstitutional centers and biomedical research groups. It is hoped networks of this type will create more potent schemes of scientific cooperation that facilitate the achievement of objectives it would be difficult to undertake in more restricted contexts.[10] At the time of writing, 3 networks exist in cardiovascular medicine[9]: "Risk factors, course and treatment of cardiovascular diseases and their molecular, and cellular mechanisms" (RECAVA) coordinated by Soler Soler at the Hospital Vall d'Hebron (Barcelona); "Genetic and environmental determinants of vascular dysfunction in hypertension, and ischemic heart disease" (HERACLES) coordinated by Marrugat de la Iglesia at the Institut Municipal d'Investigació Mèdica (IMIM) (Barcelona); and "Epidemiologic, pathophysiologic, clinical, and pathologic characteristics of sudden death in Spain" (EULALIA-MUSIC2) coordinated by Bayés de Luna at the Hospital de la Santa Creu i Sant Pau (Barcelona). Similarly, the Instituto de Salud Carlos III has been promoting Networking Biomedical Research Centers (CIBER)[11] independent research organizations dedicated to research into a single specific disease that represents a special healthcare problem, and these constitute major centers for the transfer of research.

The study of scientific collaboration helps establish groups and work networks that can be analyzed and evaluated thru bibliometric techniques and represented in what some authors call "coauthorship networks"[12,13] or "bibliometric maps."[14]

The objective of the present paper is to identify and represent graphically the networks of collaboration between authors and institutions that have published scientific papers in *Revista Española de Cardiología* between 2000 and 2005.

METHODS

Identification of Papers, Bibliographic Data and Normalization of Authors and Institutions

To undertake this study we identified research papers published in *Revista Española de Cardiología* during 2000-2005. For each paper selected we identified the name and surnames of the authors, as well as their institutional affiliation (institution, city, and country).

To normalize authorship we checked the signatures with which an individual appeared in two or more different forms, using coincidence in authors' places of work as the basic criterion of normalization. In the case of institutions, we have unified the different variants of hospital names to match the name recorded in the Spanish National Catalog of Hospitals 2005[15] and the National Registry of Universities, Centers, and Teaching.[16] Similarly, given that institutional names in many bibliographic records included two or more institutions (eg, university hospitals and universities) and in order not to lose information, we have proceeded to distinguish between these signatures by, in these instances, recording as many signatures as individual macroinstitutions could be identified for each bibliographic record.

With this information we have constructed a Microsoft Access database.

Bibliometric Indicators of Collaboration and Networks of Coauthorship and of Institutional Collaboration

Throughout the present paper we use the term "coauthorship" to refer to joint authorship of a scientific paper by 2 individuals, and "institutional collaboration"

to refer to joint authorship by different institutions. Furthermore, we distinguish between the following types of collaboration: intrainstitutional (between different units or departments of a single macroinstitution), national-interinstitutional (between institutions of the same or different autonomous regions), and international-interinstitucional, when a Spanish institution has collaborated with a non-Spanish institution. We use the term "cluster" to refer to constellations of nodes or vertices (authors or institutions) with close connecting links (relationships of coauthorship or institutional collaboration) but with sporadic connections moving away from the center.[17] "Threshold" or "intensity of collaboration" refers to the figure used to form clusters of authors and institutions, referring to frequency of coauthorship between pairs of authors or of collaboration between institutions, and reflects the more or less well-established relationships between them when it comes to jointly publishing the results of their research. The threshold has been used in different bibliometric studies as a criterion to label identifiable clusters as "research groups."[18,19]

Collaboration between authors is portrayed by calculating the number of papers, signatures, collaborations, the index of signatures/paper (ISP), or collaboration index, which is the mean number of signatures/paper; and the index of authors/paper (mean number of authors/paper considering only the different authors). Similarly, we conducted a descriptive statistical analysis of the variables studied (mean and 95% confidence interval [CI]). To compare the means of the variables in a normal distribution we used ANOVA analysis of variance, determining the equality of variances with the Levene test. These comparisons were made using the Bonferroni test for equal variances and the Tamhane T2 test for unequal variances.

To construct coauthorship networks, we identified all combinations of pairs of authors for each paper. The number of coauthorships of each paper is related to the number of authors as it is equal to m!/(m-n)!n!, where "m" is the number of individual authors and "n" the number of elements in the groups constructed, in this case 2 as we identified pairs of authors who coauthored a paper. Once coauthorship was quantified, we established a threshold of 6 o more collaborations between pairs of authors to reduce the number of nodes and links that would prevent a clear view of the network and, thus, center analysis on the more intense coauthorship relationships. The same approach was applied to institutional authorship to construct the network of interinstitutional collaboration, although in this case we applied a threshold of 3 or more collaborations.

We obtained a series of measures to permit analysis of structure or social networks. If we take agents (authors or institutions) individually, we present 3 measures of centrality or cohesion that facilitate detailed analysis of the social network studied: degree, and indices of betweenness and closeness.[20]

Degree indicates the number of different agents, a specific author or institution is directly connected with, and is obtained by identifying and subsequently quantifying relationships of coauthorship and institutional collaboration. It's a measure that reflects the greater or lesser extent of collaboration mantained by authors and institutions. Betweenness determines the extent to which an agent is situated in the middle of or between other agents in the network, permitting us to make interconnections. Betweenness measures the prestige of authors and institutions and their capacity to access and control information flow. It is calculated as the sum of the shortest paths between the 2 agents that include between them the agent in question. Closeness enables us to determine the pace of interaction between an individual agent and the other agents in the network. It reflects the "proximity" of each author or institution to the rest. It is calculated as the inverse of the sum of distances from the agent in question to the rest of the agents they are connected with.[20]

To determine the cohesion of the clusters identified, we calculated the density of each one, a measure that determines the degree of connection between members according to the relationships between the number of existing links and the number of possible links. To do so, we applied the formula 2e/n(n-1), where "e" is the number of existing links and "n" the number of agents.[20]

To calculate indicators and construct networks we used TextToPajek software developed at the Universidad Complutense de Madrid[21] and PAJEK analysis of networks software.[22]

RESULTS

Original Articles accounted for 455 (46.43%) of the 980 papers analyzed; Brief Reports accounted for 270 (27.55%) papers. Table 1 presents the distribution by year of publication and section.

Of the papers analyzed, 95.1% (n=932) were the product of collaboration between 2 or more authors, whereas only 4.9% (n=48) were the work of a single author (Table 2). We identified 6108 signatures, giving a mean of 6.23 (3.1) signatures/paper. The ISP has held practically constant, with values near to 6 over the 6-year period. We found no statistically significant differences according to year of publication, but did find significant differences according to the section where papers were published ($P<.02$). Papers published in Original Articles attained higher ISPs during the study period (mean, 7.87 [2.88]), followed by Special Articles (mean 6.59 [5.02]) and Brief Reports (mean, 5.55 [1.2]). The sections with the lowest indices were Review Articles (mean, 2.72 [1.23]), Controversies (mean, 2.75 [2.87]),

Update (mean, 2.95 [1.98]) and Images in Cardiology (mean, 3.3 [1.11]).

The number of different authors published during the period was 2927, with a mean of 2.99 authors/paper (Table 2). The overall mean of authors/paper for the entire period is lower than the annual mean because the number of different authors fell as the study period progressed.

Table 3 presents the 44 authors who published >11 papers and their patterns of collaboration, including the number of signatures and collaborators in papers in which they have intervened and the signatures/paper and authors/paper indices. Some authors stand out, even though they are not among the leaders in the productivity ranking, gathering a high number of signatures and a wide nucleus of collaborators, from which they derive high a ISP and high mean of authors/paper.

Applying a threshold of 6 or more coauthored papers has identified 25 clusters of authors with a high intensity of collaboration, consisting of 112 authors from 29 different institutions. Of the 73 most productive authors, 54 (73.97%) are participate in one or other of these clusters; this increases if we consider the 24 most productive authors (>14 papers), as 20 of them belong to one or other of the clusters (83.33%). Similarly, of the 112 authors in these clusters we identified 58 (51.78%) who, although not at the top of the productivity ranking (they stand in positions between 74 and 197), are characterized by the high intensity of their collaboration with other authors. The cluster with most authors was that led by M. Valdés Chavarri, composed of 14 authors; next are clusters around F.J. Chorro Gascó/J. Sanchís Forés, and M.P. Anguita Sánchez/D. Mesa Rubio, with 9 authors in each case (Figure 1). Among the clusters with 9 or more members, the highest cohesion index is held by F.J. Chorro Gascó/J. Sanchís Forés (0.64); among clusters of 5-7 members those centered on A. Medina Fernández Aceituno and J. Soler Soler stand out, with cohesion indices of 1 and 0.9, respectively (Table 4).

Table 5 presents the statistical values of centrality of authors calculated considering all coauthorships identified.

TABLE 1. **Number of Papers Published by Year and Section in *Revista Española de Cardiología* (2000-2005) and Selected for the Purposes of the Study**

Sections	2000	2001	2002	2003	2004	2005	Total (%)
Original articles	73	80	80	81	68	73	455 (46.43%)
Brief reports	49	50	49	35	40	47	270 (27.55%)
Images in cardiology	16	17	12	12	12	12	81 (8.26%)
Special articles*	27 (2)	13 (2)	5 (3)	6 (2)	8 (3)	9 (3)	68 (6.94%)
Update	6	9	13	11	10	12	61 (6.22%)
Review articles	6	7	9	6	7	4	39 (3.98%)
Controversies	2	2	–	–	2	–	6 (0.61%)
Total	179	178	168	151	147	157	980 (100%)

*We excluded 15 papers from the Special Articles section (in parentheses) which were not considered research papers.

TABLE 2. **Distribution of the Number of Signatures and the Number of Authors of the Papers Published in *Revista Española de Cardiología* (2000-2005)***

Year	Number of Papers	Number of Coauthored Papers, %	Number of Signatures	Mean Signatures/ Paper	95% CI	Number of Authors	Mean Authors/ Paper	Maximum Number of Authors/Paper
2000	179	168 (93.85%)	1110	6.20	5.70-6.70	761	4.25	31
2001	178	169 (94.94%)	1038	5.83	5.43-6.23	828	4.65	14
2002	168	161 (95.83%)	1002	5.96	5.54-6.39	744	4.42	14
2003	151	143 (94.7%)	988	6.54	6.02-7.07	733	4.85	17
2004	147	140 (95.23%)	953	6.48	5.94-7.02	754	5.12	22
2005	157	151 (96.18%)	1017	6.48	5.97-6.98	877	5.58	20
Total	980	932 (95.1%)	6108	6.23	6.04-6.43	2927†	2.99†	31

*CI indicates confidence interval.
†To calculate these values we took account of the different authors published in 2000-2005.

TABLE 3. **Authors With >11 Papers and Patterns of Collaboration in *Revista Española de Cardiología* (2000-2005)**

Author	Number of Papers	Papers in Collaboration,%	Number of Signatures	Number of Collaborators	Mean Signatures /Paper	Mean Authors/Paper
1. Valdés Chavarri, Mariano	36	36 (100%)	282	92	7.83	2.55
2. Chorro Gascó, Francisco J	20	20 (100%)	189	51	9.45	2.55
3. Sanchís Forés, Juan	20	20 (100%)	190	51	9.5	2.55
4. Soler Soler, Jordi	19	19 (100%)	141	70	7.42	3.68
5. Benito Bartolomé, Fernando C	18	14 (77.78%)	58	23	3.22	1.28
6. Candell Riera, Jaume	18	17 (94.44%)	149	79	8.28	4.39
7. López Palop, Ramón	18	18 (100%)	135	37	7.5	2.05
8. Anguita Sánchez, Manuel Pablo	17	15 (88.23%)	114	32	6.7	1.88
9. Bertomeu Martínez, Vicente	17	17 (100%)	184	79	10.82	4.65
10. Bodí Peris, Vicent	17	17 (100%)	160	41	9.41	2.41
11. Goicolea Ruigómez, Francisco Javier	17	17 (100%)	114	50	6.7	2.94
12. Marrugat de la Iglesia, Jaume	17	17 (100%)	156	75	9.18	4.41
13. Mesa Rubio, Dolores	17	17 (100%)	136	38	8	2.23
14. Sobrino Daza, José Antonio	17	17 (100%)	107	38	6.29	2.23
15. Bosch Genover, Xavier	16	16 (100%)	114	61	7.12	3.81
16. Climent Payá, Vicente E	16	16 (100%)	147	58	9.19	3.62
17. Marín Ortuño, Francisco	16	16 (100%)	141	58	8.81	3.62
18. Pinar Bermúdez, Eduardo	16	16 (100%)	125	35	7.81	2.19
19. Teresa Galván, Eduardo of	16	16 (100%)	116	46	7.25	2.87
20. Castro Beiras, Alfonso	15	15 (100%)	114	70	7.6	4.67
21. García Alberola, Arcadio	15	15 (100%)	103	42	6.87	2.8
22. González Juanatey, José Ramón	15	15 (100%)	97	64	6.47	4.27
23. Llácer Escorihuela, Ángel	15	15 (100%)	145	37	9.67	2.47
24. López Sendón, José Luis	15	15 (100%)	124	65	8.27	4.33
25. Lozano Martínez Luengas, Íñigo	14	14 (100%)	116	33	8.28	2.36
26. Moreno Gómez, Raúl	14	13 (92.86%)	111	53	7.93	3.78
27. San Román Calvar, José Alberto	14	14 (100%)	120	81	8.57	5.78
28. Merino Llorens, José Luis	13	13 (100%)	74	30	5.69	2.31
29. Vallés Belsué, Federico	13	13 (100%)	110	30	8.46	2.31
30. Zamorano Gómez, José Luis	13	13 (100%)	96	44	7.38	3.38
31. Aguadé Bruix, Santiago	12	12 (100%)	95	41	7.92	3.42
32. Alfonso Manterola, Fernando	12	12 (100%)	73	44	6.08	3.67
33. Almenar Bonet, Luis	12	6 (50%)	59	26	4.91	2.17
34. Almendral Garrote, Jesús	12	12 (100%)	88	54	7.33	4.5
35. Almería Valera, Carlos	12	12 (100%)	86	37	7.17	3.08
36. Castell Conesa, Joan	12	12 (100%)	96	42	8	3.5
37. Mantilla González, Ramón	12	12 (100%)	84	39	7	3.25
38. Medina Fernández Aceituno, Alfonso	12	12 (100%)	94	43	7.83	3.58
39. Oliver Ruiz, José María	12	11 (100%)	54	27	4.5	2.25
40. Payá Serrano, Rafael	12	12 (100%)	139	53	11.58	4.42
41. Peinado Peinado, Rafael	12	12 (100%)	72	32	6	2.67
42. Picó Aracil, Francisco	12	12 (100%)	96	21	8	1.75
43. Ruipérez Abizanda, Juan Antonio	12	12 (100%)	87	41	7.25	3.42
44. Sanz Romero, Ginés	12	12 (100%)	90	43	7.5	3.58

Some authors who do not occupy leading positions in the productivity ranking exercise an outstanding role as "intermediaries" with other authors or of "proximity" to these in the coauthorship network.

In 504 papers (51.43%) we found observed some type of (intrainstitutional or interinstitutional) collaboration, in contrast with 476 papers (48.57%) in which there is no collaboration. Considering the 473 papers in collaboration in which Spanish institutions intervene (Table 6), we find intrainstitutional collaboration comes first (40.87%), closely followed by collaboration between institutions within the same autonomous region (39.7%).

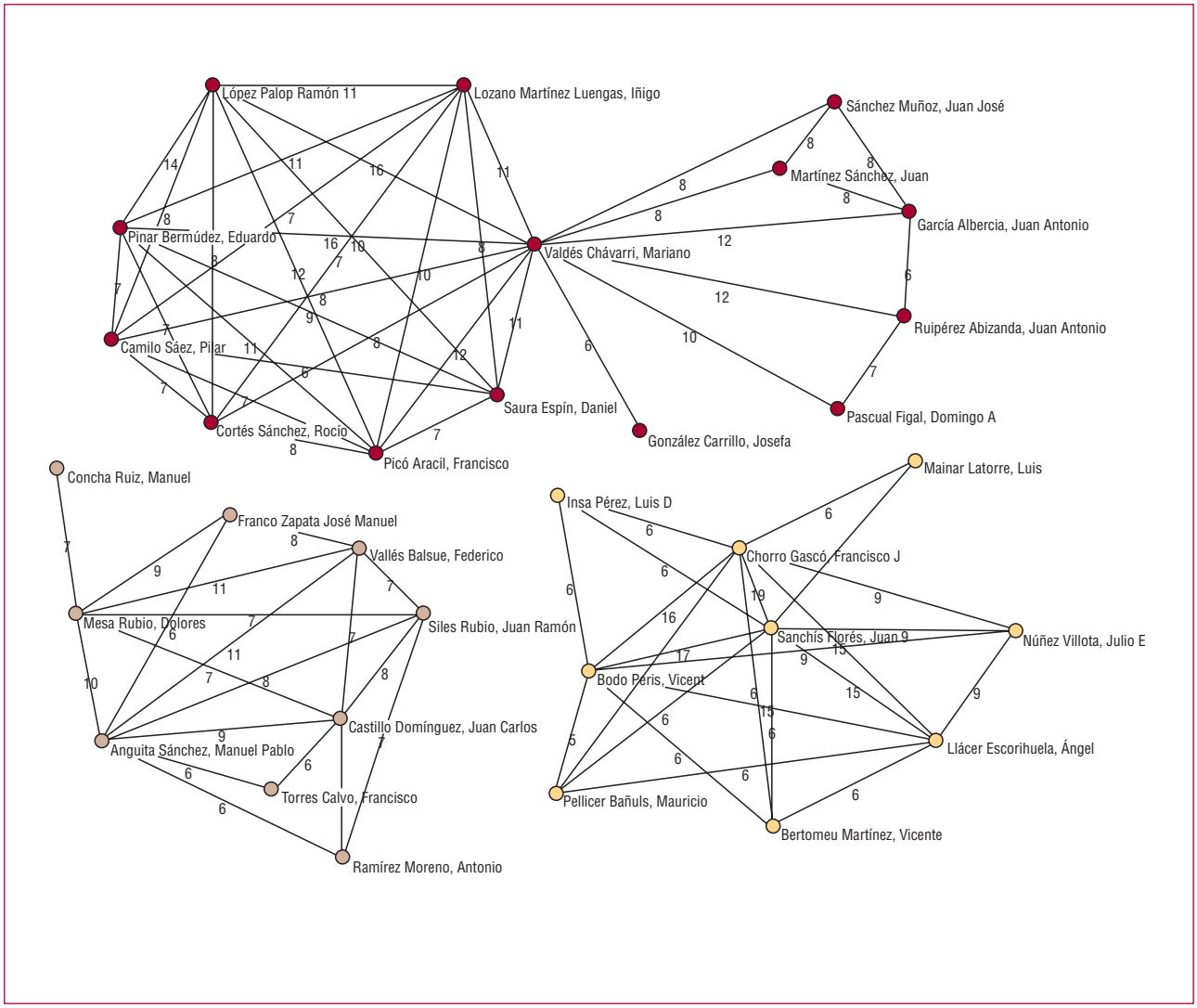

Figure 1. Clusters 1 to 3 (9 or more members) with an intensity of collaboration of 6 or more coauthors.

Some distance behind that we find collaboration between institutions from different autonomous regions (15.41%) and international collaboration (4.02%). It is important to note a tendency towards increased collaboration when papers are analyzed by year of publication, as the number of papers authored in collaboration has grown from 43.02% in 2000 to 56.69% in 2005, when the highest collaboration index of the whole study period appears (Table 6).

Table 7 presents the 42 most productive institutions (>9 papers) and their patterns of interinstitutional collaboration. The productivity ranking is headed by Complejo Universitario La Paz, (Madrid), with 50 papers; Hospital General Universitario Gregorio Marañón (Madrid), 45 papers; Hospitals Vall d'Hebron (Barcelona) and Hospital Universitario Virgen de la Arrixaca (Murcia), 40 papers; Clínica Universitaria de San Carlos (Madrid), 39; Hospital Clínic i Provincial de Barcelona, 34; and Hospital Ramón y Cajal (Madrid), 33. Another 12 institutions published >20 papers and 23 institutions, 10-19 papers.

To establish institutional collaboration networks we applied a threshold of 3 or more collaborations, representing the differing intensity of collaboration through different thicknesses in the links. Figure 2 shows the principal nucleos of the institutional network. In terms of statistics of centrality of institutional collaboration (Table 8), the principal agents in the network are, first, Hospital Universitario La Fe (Valencia) and, second, Hospital de la Santa Creu i Sant Pau (Barcelona), for the 3 indicators. Other institutions that occupy an outstanding place in terms of the number of different institutions with which they collaborated (degree) are Institut Municipal d'Investigació Mèdica (Barcelona), Hospital Clínic i Provincial de Barcelona and Hospital General Universitario Gregorio Marañón (Madrid); all 3 placed

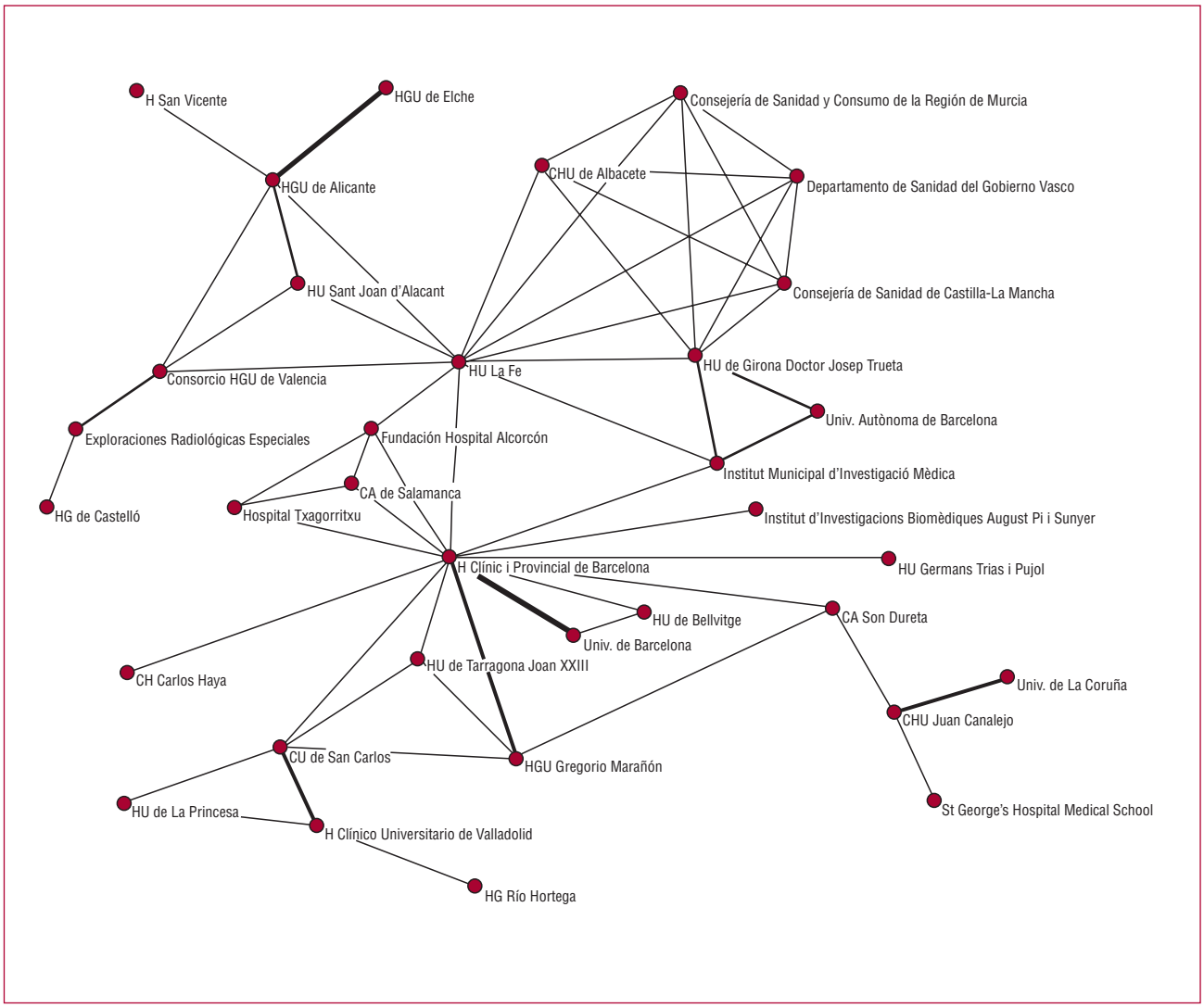

Figure 2. Principal nucleus of network of institutional collaborations with intensity of collaboration of 3 or more collaboration relationships.

among the first 10 in the betweenness ranking. Following them, we find Complejo Asistencial de Salamanca, Complejo Universitario La Paz (Madrid), Hospital Universitario Virgen de la Arrixaca (Murcia) and Complejo Hospitalario Universitario Juan Canalejo (A Coruña); all these also play an outstanding role in the rest of the indicators.

DISCUSSION

The method applied has enabled us to identify the most productive authors and institutions, and the composition of 25 clusters of authors who collaborate intensively in cardiovascular medicine in Spain, all of whom published in *Revista Española de Cardiología* during 2000-2005, characterizing their scientific activities through bibliometrics indicators. However, we should make some observations on the method applied.

1. The scientific production analyzed has been drawn exclusively from *Revista Española de Cardiología*. An exhaustive, complete review of cardiovascular medicine would need to take into account all the Spanish journals, as well as the scientific production of Spanish authors in journals published abroad. However, the method applied has the advantage that, as we are dealing with a study conducted on one of the clinical journals edited in Spain with higher impact factor in the scientific community, the results obtained represent a panorama of the nucleus of greater repercussion and quality of research in Spain.[23]

2. The problems of normalization. The importance of normalizing names of authors signing scientific papers is fundamental in coauthorship analysis studies to avoid errors caused by failing to recognize different forms of the name and surnames of a single author, or considering scientific production of 2 or more different authors with

TABLA 4. **Clusters of Authors Identified Through Analysis of Intensiveness of Coauthorship of Papers Published in *Revista Española de Cardiología* (2000-2005), Indicating Cohesion and Productivity Ranking of each Author***

		Authors	
Cluster/Cohesion	**Number of Authors in Cluster/Institutions**	**Author**	***Ranking***
Cluster 1	14	Valdés Chávarri, M	1
Cohesion=0.41	Hospital Universitario Virgen de la Arrixaca (Murcia)	López Palop, R	5-7
		Pinar Bermúdez, E	15-19
		García Alberola, A	20-24
		Lozano Martínez Luengas, I	25-27
		Picó Aracil, F	31-44
		Ruipérez Abizanda, JA	31-44
		Saura Espín, D	45-55
		Pascual Figal, DA	56-73
		Carrillo Sáez, P	74-98
		Cortés Sánchez, R	99-122
		Sánchez Muñoz, JJ	99-122
		Martínez Sánchez, J	99-122
		González Carrillo, J	153-197
Cluster 2	9	Chorro Gascó, FJ	2-3
Cohesion=0.64	Hospital Clínico Universitario (Valencia)	Sanchís Forés, J	2-3
	Hospital Universitario Sant Joan d'Alacant	Bertomeu Martínez, V	8-14
		Bodí Peris, V	8-14
		Llácer Escorihuela, A	20-24
		Núñez Villota, JE	74-98
		Mainar Latorre, L	99-122
		Insa Pérez, LD	123-152
		Pellicer Bañuls, M	153-197
Cluster 3	9	Anguita Sánchez, MP	8-14
Cohesion=0.53	Hospital Universitario Reina Sofía (Córdoba)	Mesa Rubio, D	8-14
	Hospital Costa del Sol (Málaga)	Vallés Belsué, F	28-30
		Franco Zapata, JM	56-73
		Ramírez Moreno, A	56-73
		Castillo Domínguez, JC	74-98
		Siles Rubio, JR	74-98
		Concha Ruiz, M	99-122
		Torres Calvo, F	153-197
Cluster 4	7	Hornero Sos, F	45-55
Cohesion=0.67	Consorcio Hospital General Universitario de Valencia	Montero Argudo, JA	56-73
		Cánovas López, SJ	74-98
		García Fuster, R	74-98
		Gil Albarova, O	74-98
		Dalmau Sorlí, MJ	99-122
		Bueno Codoñer, M	153-197
Cluster 5	7	Teresa Galván, E	15-19
Cohesion=0.57	Complejo Hospitalario Virgen de la Victoria (Málaga)	Gómez Doblas, JJ	45-55
		Jiménez Navarro, MF	56-73
		Rodríguez Bailón, I	99-122
		Alonso Briales, JH	123-152
		Cabrera Bueno, F	123-152
		Hernández García, JM	153-197
Cluster 6	6	Climent Payá, VE	15-19
Cohesion=0.53	Hospital General Universitario de Alicante	Marín Ortuño, F	15-19
	Hospital Universitario La Fe (Valencia)	Sogorb Garri, F	45-55
	Hospital General Universitario de Elche (Alicante)	García de Burgos Rico, F	74-98
		Jordán Torrent, AJ	99-122
		Martínez Martínez, JG	123-152

(Continued on following page)

TABLA 4. **Clusters of Authors Identified Through Analysis of Intensiveness of Coauthorship of Papers Published in *Revista Española de Cardiología* (2000-2005), Indicating Cohesion and Productivity Ranking of each Author* *(continued)***

		Authors	
Cluster/Cohesion	**Number of Authors in Cluster/Institutions**	**Author**	***Ranking***
Cluster 7	5	Soler Soler, J	4
Cohesion=0.9	Hospital Vall d'Hebron (Barcelona)	Candell Riera, J	5-7
		Castell Conesa, J	31-44
		Aguadé Bruix, S	31-44
		Oller Martínez, G	153-197
Cluster 8	5	Medina Fernández Aceituno, A	28-30
Cohesion=1	Complejo Hospitalario Doctor Negrín (Las Palmas)	Suárez de Lezo, J	56-73
	Hospital Universitario Reina Sofía (Córdoba)	Pan Álvarez-Ossorio, M	123-152
		Romero Moreno, M	153-197
		Segura, J	153-197

*Number ranges indicate >1 author with the same number of papers.

TABLE 5. **Principal Agents in Coauthorship Networks of Papers Published in *Revista Española de Cardiología* (2000-2005)**

Degree		**Betweenness × 100**		**Closenness × 100**	
Author	**Value**	**Author**	**Value**	**Author**	**Value**
1. Valdés Chávarri, Mariano	92	1. López Sendón, José Luis	4.65	1. Alegría Ezquerra, Eduardo	26.68
2. San Román Calvar, José Alberto	81	2. Alegría Ezquerra, Eduardo	4.19	2. Bardají Ruiz, Alfredo	26.66
3. Bertomeu Martínez, Vicente	79	3. San Román Calvar, José Alberto	4.18	3. Arós Borau, Fernando	26.33
4. Candell Riera, Jaume	79	4. Cruz Fernández, José María	3.61	4. González Juanatey, José Ramón	26.3
5. Marrugat de la Iglesia, Jaume	75	5. Castro Beiras, Alfonso	3.57	5. Placer Peralta, Lluís J	26.24
6. Arós Borau, Fernando	72	6. González Juanatey, José Ramón	3.43	6. San Román Calvar, José Alberto	26.18
7. Castro Beiras, Alfonso	70	7. Cosín Aguilar, Juan	3.15	7. Castro Beiras, Alfonso	25.87
8. Soler Soler, Jordi	70	8. Augé Sanpera, José María	2.81	8. Marín Huerta, Emilio	25.84
9. Alegría Ezquerra, Eduardo	66	9. Arós Borau, Fernando	2.67	9. Alonso Martín, Joaquín	25.82
10. López Sendón, José Luis	65	10. Valdés Chávarri, Mariano	2.58	10. Bosch Genover, Xavier	25.73
11. González Juanatey, José Ramón	64	11. Candell Riera, Jaume	2.56	11. Alonso Gómez, Ángel María	25.65
12. Cabadés O'Callaghan, Adolfo	62	12. Alonso Martín, Joaquín	2.49	12. Palencia Pérez, Miguel A	25.45
13. Bosch Genover, Xavier	61	13. Placer Peralta, Lluís J	2.47	13. Cabadés O'Callaghan, Adolfo	25.29
14. Bardají Ruiz, Alfredo	60	14. Soler Soler, Jordi	2.44	14. Luengo Fernández, Emilio	25.24
15. Climent Payá, Vicente E	58	15. Bardají Ruiz, Alfredo	2.29	15. Candell Riera, Jaume	25.24
16. Marín Ortuño, Francisco	58	16. Bertomeu Martínez, Vicente	2.29	16. López Bescós, Lorenzo	25.21
17. Sogorb Garri, Francisco	56	17. Baño Rodrigo, Antonio	2.22	17. Ferrero, José Antonio	25.2
18. Almendral Garrote, Jesús	54	18. Velasco Rami, José A de	2.2	18. Cosín Aguilar, Juan	25.1
19. López Bescós, Lorenzo	54	19. Alfonso Manterola, Fernando	2.19	19. Crespo, Marisa	25.1
20. Moreno Gómez, Raúl	53	20. Maggioni, Aldo P	2.06	20. Muñiz García, Javier	25.09

the same names as belonging to one individual. We have tried to avoid these errors thru careful manual supervision of the bibliographic references managed, as described in detail above (Methods).

3. The study of the relationships between scientific papers. Analysis of references and bibliographic citations between scientific papers enjoys a long tradition in bibliometric studies.[24] However, analysis of coauthorship to construct author networks is a more recent object of study[12] and uniform criteria to identify communities or research groups within previously constructed networks do not exist. This represents an obstacle to the interpretation of results, especially when comparing earlier studies conducted with different methods.[18,19]

Independently of the country or discipline being studied, one of the principal phenomena that can be seen in

TABLE 6. **Number of Collaborations Between Institutions Grouped by Type of Collaboration and Total Number of Papers Published in Collaboration in *Revista Española de Cardiología* (2000-2005)**

	Number of Collaborations						Total
Types of Collaboration	2000	2001	2002	2003	2004	2005	2000-2005, %
Intrainstitutional collaboration (type 1)	43	37	39	39	41	45	244 (40.87%)
Interinstitutional collaboration							
Same autonomous region (type 2a)	34	42	36	37	42	46	237 (39.7%)
Different autonomous regions (type 2b)	13	20	13	14	9	23	92 (15.41%)
International collaboration (type 3)	3	4	5	6	4	2	24 (4.02%)
Total, %*	93 (15.58%)	103 (17.25%)	93 (15.58%)	96 (16.08%)	96 (16.08%)	116 (19.43%)	597 (100%)
Number of papers in collaboration (%)†	77 (43.02%)	83 (46.63%)	73 (43.45%)	74 (49.01%)	77 (52.38%)	89 (56.69%)	473 (100%)

*Note that in number of collaborations, some papers include no collaboration and others involve more than one type of collaboration. To calculate percentages we did not include 31 papers authored in collaboration but not signed by Spanish institutions.
†We took into account when calculating the 473 papers signed by at least one Spanish institution. Percentages are calculated with respect to total number of papers per year, reported in Table 1.

diachronic studies of scientific collaboration is the trend towards a growth in cooperation between researchers, as measured by the ISP.[25] In biomedicine, a recent study of the number of signatures/paper has highlighted the fact that the mean has increased from 4.5 in 1980 to 6.9 in 2000.[26] In Spanish medical journals, the ISP has risen from 3.47 at the beginning of the 1980s to 4.59 at the beginning of the 1990s.[27] In cardiovascular medicine, in 1990-1993, the ISP of Spanish scientific production included in the Science Citation Index was 5.78,[19] a trend to growth that has been maintained, with the ISP currently at 6.23. However, we should bear in mind that in some article types the number of signatures permitted has been limited, which means the ISP tends to be lower.

The tendency to increase the number of signatures/paper may be due to different causes, among which we should point out the complex, interdisciplinary nature of current medical practice[28,29] and, as a consequence, the need to collaborate with external teams.[30] The ISP obtained is greater than that found in journals such as *Revista Española de Anestesiología y Reanimación* (ISP=3.1),[31] *Atención Primaria* (ISP=3.77),[32] *Farmacia Clínica* (ISP=3.86),[33] and in fields such as drug dependency (ISP=4.1)[34] and HIV/Aids (ISP=4.72).[35] However, it is very similar to that of *Actas Urológicas Españolas* (ISP=6.1).[36] The number of signatures should be viewed in the light of the abuse of signatures in scientific papers in the form of hyper-authorship that does not correspond to the real contribution of the authors to papers but to a variety of reasons, among which we would highlight those related with the increase in scientific prestige and obtaining sources of finance.[37-39] To avoid abuses in the coauthorship of scientific publications various approaches and initiatives have arisen, among which the recommendations contained in the International Committee of Editors of Medical Journals' proposal should be noted. Their view on the signatures of papers[40] has been criticized as excessively rigid and impossible to fulfill[41] in favor of others which propose describing precisely the contribution of the signatories[42] or designating one as responsible for the publication.[43] It is beyond the scope of this paper to identify the influence these factors may have had on the ISP of *Revista Española de Cardiología*

In parallel with the increased ISP in scientific papers, we note increased productivity of authors. In fact, 32.2% of authors responsible for Spanish scientific production in cardiovascular medicine included in the SCI in 1990-1993 published >1 paper,[19] and this rose to 35.76% in the present study.

The identification of the most productive authors and of clusters of authors who collaborate closely can be of use in decision-making both in public research organizations and by coordinators of networks when they have reliable information about consolidated research groups and their members. We have detected 10 clusters in which one of the institutions involved is included in RETIC. Similarly, 2 of the coordinators of these networks (Soler Soler and Marrugat de la Iglesia) are among the most productive authors, although a third (Bayés de Luna) has not been identified in the present study because, with few exceptions, the majority of his papers appear in journals published abroad. The existence of numerous clusters indicates that, despite policies of promoting interinstitutional, multidisciplinary research, there remain numerous research groups with no cohesion among themselves, with a limited number of members, with a mean of 4.48 authors for the 25 clusters formed with a threshold of collaboration of 6 or more papers. However, if we consider a threshold of 4 or more coauthored papers, the number of clusters would rise to 46, made up of 278 authors with a mean of 6.04 authors

TABLE 7. **More Productive Institutions and Patterns of Interinstitutional Collaboration of Papers Published in *Revista Española de Cardiología* (2000-2005)***

Institution	Number of Papers	Number Papers in Collaboration, %	Number of Signatures	Number of Different Institutions That Have Collaborated	Number of Collaborative Relationships	Value of More Intensive Collaboration/Institution
1. CU La Paz (Madrid)	50	11 (22%)	88	31	38	3/HU Puerta de Hierro (Madrid)
2. HGU Gregorio Marañón (Madrid)	45	23 (51.11%)	99	32	54	7/H Clínic i Provincial de Barcelona
3. Hospitals Vall d'Hebrón (Barcelona)	40	13 (32.5%)	59	18	19	2/HU de Bellvitge (Barcelona)
4. HU Virgen de la Arrixaca (Murcia)	40	13 (32.5%)	74	30	34	2/HGU Gregorio Marañón (Madrid)
5. CU de San Carlos (Madrid)	39	16 (41.02%)	75	19	36	6/H Clínico Universitario de Valladolid
6. H Clínic i Provincial de Barcelona	34	28 (82.35%)	116	33	82	13/Univ de Barcelona
7. H Ramón y Cajal (Madrid)	33	17 (51.51%)	63	17	30	11/Univ de Alcalá (Madrid)
8. Fundación de Gestión Sanitaria de l'Hospital de la Santa Creu i Sant Pau (Barcelona)	30	13 (43.33%)	73	37	43	2/CU La Paz (Madrid)
9. Consorcio HGU de Valencia	29	13 (44.83%)	64	21	35	6/Exploraciones Radiológicas Especiales/ERESA (Valencia)
10. HU Reina Sofía (Córdoba)	28	10 (35.71%)	47	10	19	5/HC Doctor Negrín (Las Palmas)
11. H 12 de Octubre (Madrid)	27	11 (40.74%)	44	16	17	2/CU de San Carlos (Madrid)
12. H Clínico Universitario (Valencia)	26	21 (80.77%)	68	24	42	12/Univ de Valencia
13. HGU de Alicante	25	16 (64%)	62	16	37	9/HGU de Elche (Alicante)
14. HU Marqués de Valdecilla (Cantabria)	23	9 (39.13%)	60	21	37	3/Univ de Cantabria
15. HC Virgen de la Victoria (Málaga)	22	9 (40.91%)	45	22	23	2/UHC Juan Canalejo (A Coruña)
16. UHC Juan Canalejo (A Coruña)	21	15 (71.43%)	68	29	47	5/Univ de A Coruña
17. HU La Fe (Valencia)	21	13 (61.9%)	109	52	88	4/Consorcio HGU de Valencia
18. HU Puerta de Hierro (Madrid)	21	11 (52.38%)	47	22	26	3/CU La Paz (Madrid)
19. Univ de Barcelona	21	20 (95.24%)	50	14	29	13/H Clinic i Provincial de Barcelona
20. HC Virgen del Rocío (Sevilla)	19	7 (36.84%)	39	18	20	2/HC Virgen de las Nieves (Granada)
21. H Clínico Universitario de Valladolid	19	13 (68.42%)	52	21	33	6/CU de San Carlos (Madrid)
22. CA de Salamanca	18	8 (44.44%)	63	31	45	4/Fundación Hospital Alcorcón
23. Univ de Valencia	17	17 (100%)	50	17	33	12/H Clínico Universitario (Valencia)
24. CU de Vigo (Pontevedra)	16	6 (23.08%)	25	8	9	2/HC de Pontevedra
25. Clínica Universitaria de Navarra	15	13 (86.67%)	46	26	33	7/Univ de Navarra
26. Institut Municipal d'Investigació Mèdica/IMIM (Barcelona)	15	15 (100%)	73	36	58	6/Univ Autònoma de Barcelona
27. Fundación Jiménez Díaz (Madrid)	14	6 (42.86%)	30	15	16	2/Univ Autónoma de Madrid
28. HC Doctor Negrín (Las Palmas)	13	8 (61.54%)	27	8	14	5/HU Reina Sofía (Córdoba)
29. UHC de Santiago (A Coruña)	13	6 (46.15%)	30	22	24	2/CU La Paz (Madrid)
30. HU de Bellvitge (Barcelona)	13	10 (76.92%)	41	21	31	3/H Clinic i Provincial de Barcelona
31. Pontificia Univ Católica de Chile	12	3 (25%)	9	5	6	2/H Clínico de Santiago de Chile
32. Univ de Alcalá (Madrid)	12	12 (100%)	30	6	18	11/H Ramón y Cajal (Madrid)
33. CA Son Dureta (Palma de Mallorca)	11	10 (90.91%)	47	27	36	3/HGU Gregorio Marañón
34. CH Virgen de las Nieves (Granada)	11	6 (54.54%)	31	17	20	2/HU Marqués de Valdecilla (Cantabria)
35. UHC de Badajoz (Badajoz)	11	3 (27.27%)	26	13	15	2/HU Marqués de Valdecilla (Cantabria)
36. Exploraciones Radiológicas Especiales/ERESA (Valencia)	11	11 (100%)	25	6	14	6/Consorcio HGU de Valencia
37. H de Cruces (Vizcaya)	11	2 (18.18%)	8	6	6	1/H Clinic i Provincial de Barcelona
38. HGU de Elche (Alicante)	11	10 (90.91%)	31	9	21	9/HGU de Alicante
39. HU Germans Trias i Pujol (Barcelona)	11	5 (45.45%)	30	13	19	3/H Clinic i Provincial de Barcelona
40. HU Sant Joan d´Alacant	11	8 (72.73%)	42	19	31	5/HGU de Alicante
41. Fundación Hospital Alcorcón (Madrid)	10	7 (70%)	48	28	41	4/H Clinic i Provincial de Barcelona
42. HU Doctor Peset (Valencia)	10	6 (60%)	26	13	20	3/Univ de Valencia

*Institution which has maintained a greater number of collaborations with (when >1, the most productive is used).

TABLE 8. **Principal Agents of Interinstitutional Collaboration Network of Papers Published in *Revista Española de Cardiología* (2000-2005)**

Degree		Betweenness × 1100		Closenness × 1100	
Institution	Value	Institution	Value	Institution	Value
1. HU La Fe (Valencia)	52	1. HU La Fe (Valencia)	7.55	1. HU La Fe (Valencia)	32.41
2. H de la Santa Creu i Sant Pau (Barcelona)	37	2. H de la Santa Creu i Sant Pau (Barcelona)	5.95	2. H de la Santa Creu i Sant Pau (Barcelona)	32.35
3. Institut Municipal d'Investigació Mèdica (Barcelona)	36	3. HU Virgen de la Arrixaca (Murcia)	4.45	3. CA de Salamanca	31.07
4. H Clínic i Provincial de Barcelona	33	4. HGU Gregorio Marañón (Madrid)	3.67	4. H Clínic i Provincial de Barcelona	30.81
5. HGU Gregorio Marañón (Madrid)	32	5. CU La Paz (Madrid)	3.56	5. HGU Gregorio Marañón (Madrid)	30.76
6. CA de Salamanca	31	6. Univ Autónoma de Madrid	3.55	6. Clínica Universitaria of Navarra	30.14
7. CU La Paz (Madrid)	31	7. CA Son Dureta (Palma de Mallorca)	3.21	7. Fundación Hospital Alcorcón (Madrid)	30.09
8. HU Virgen de la Arrixaca (Murcia)	30	8. HCU de Valladolid	2.90	8. CU La Paz (Madrid)	29.94
9. CHU Juan Canalejo (A Coruña)	29	9. Institut Municipal d'Investigació Mèdica (Barcelona)	2.82	9. CA Son Dureta (Palma de Mallorca)	29.12
10. Fundación Hospital Alcorcón (Madrid)	28	10. H Clínic i Provincial de Barcelona	2.68	10. CHU Juan Canalejo (A Coruña)	28.75
11. CA Son Dureta (Palma de Mallorca)	27	11. CHU Juan Canalejo (A Coruña)	2.65	11. HU Virgen de la Arrixaca (Murcia)	28.62
12. HU de Girona Doctor Josep Trueta	27	12. Clínica Universitaria de Navarra	2.56	12. HU de Bellvitge (Barcelona)	28.53
13. Clínica Universitaria de Navarra	26	13. HC Virgen de la Victoria (Málaga)	2.54	13. CU de San Carlos (Madrid)	28.48
14. Univ Autònoma de Barcelona	26	14. HCU de Valencia	2.51	14. HC Carlos Haya (Málaga)	28.21
15. HCU de Valencia	24	15. HC Virgen del Rocío (Sevilla)	2.29	15. Institut Municipal d'Investigació Mèdica (Barcelona)	28.21
16. HC Virgen de la Victoria (Málaga)	22	16. HU Marqués de Valdecilla (Cantabria)	2.15	16. HC Virgen de la Victoria (Málaga)	28.13
17. CHU de Albacete	22	17. CA de Salamanca	2.1	17. CHU de Santiago (A Coruña)	28.13
18. CHU de Santiago (A Coruña)	22	18. HU de Bellvitge (Barcelona)	2.08	18. HCU de.Valencia	28.04
19. HU Puerta de Hierro (Madrid)	22	19. HU Puerta de Hierro (Madrid)	2.01	19. Hospital Txagorritxu (Álava)	27.91
20. Consorcio HGU de Valencia	21	20. CU de San Carlos (Madrid)	1.93	20. Fundación Jiménez Díaz (Madrid)	27.82

per cluster, and the largest cluster consisting of 41 authors. For a threshold of 3 or more coauthored papers, the number of clusters is 58, with a mean of 8.36 authors per cluster, linking 187 authors directly or thru intermediaries. If we increase the threshold for institutional collaboration, only a very small number appears linked by stable collaborative relations. So, for a threshold of 3 or more papers in collaboration, the principal nucleus is formed of 34 institutions, with 7 subgroups made up of 18 institutions isolated from the principal nucleus. For a threshold of 4 or more papers in collaboration the principal nucleus is formed by only 10 institutions, with 6 subgroups made up of 20 institutions isolated from the principal nucleus. Together with the limited number of institutions that maintain stable, consolidated, collaborative interinstitutional relations, another of the most significant aspects is the marked nature of cooperation between institutions and within autonomous regions as together these add up to 80.57% of collaborations.

Measures of centrality permit us to identify authors and institutions that occupy outstanding positions in the networks of coauthorship and institutional collaboration, on the basis of indicators such as number of authors and institutions which they have collaborated with, implying a greater capacity to access and exchange information.

If we only considered papers in the "Original articles" section when forming networks, we identify the same clusters of authors and a similar network of institutional collaborations. From this, we deduce that this section constitutes the nucleus of the journal where the research conducted by the regular collaborators of the journal are published.

CONCLUSIONS

The most relevant conclusions of the present study are:

1. Some 95.1% of papers in *Revista Española de Cardiología* are the product of collaboration between 2 or more authors, with indices of signatures/paper and authors/paper similar or above those of other journals and disciplines in biomedicine.

2. We identified various clusters of authors who constitute established groups that can be considered the

cutting edge of research in cardiology published in Spanish.

3. Despite the high number of coauthored papers (95.1%) and policies that promote interinstitutional, multidisciplinary research, numerous isolated research groups, with a limited number of members, remain.

4. Even though 51.43% of papers are the product of collaboration between institutions, this mainly occurs within institutions and autonomous regions, although in 2005 we did note a clear increase in collaboration between autonomous regions.

In addition to the topics dealt with in the present paper, we could go more deeply into the scientific activity of the groups identified thru bibliometric indicators of productivity, repercussion and impact.[14,18] Given the dynamic nature of science and of research groups, it would also be interesting to study the evolution of these groups over time and to broaden the scope of our analysis of Spanish cardiovascular research activity to other journals, both national and international.

REFERENCES

1. Gómez I, Fernández MT, Bordons M, Morillo F. La producción científica española en Medicina en los años 1994-1999. Rev Clin Esp. 2004;204:75-88.
2. Camí J, Suñén-Piñol E, Méndez-Vásquez R. Mapa bibliométrico de España 1994-2002: biomedicina y ciencias de la salud. Med Clin (Barc). 2005;124:93-101.
3. The Institute for Scientific Information. Journal Citation Reports [accedido 16 Jun 2006]. Disponible en: http://portal.isiknowledge. com/
4. Aleixandre R, Valderrama JC, editores. Factor de impacto potencial de las revistas médicas españolas [accedido 2 Dic 2005]. Disponible en: ime.uv.es/imecitas/impacto_ime.asp.
5. Klein JT. Interdisciplinary needs: the current context. Libr Trenes. 1996;45:134-54.
6. Bordons M, Zulueta MA. La interdisciplinariedad en los grupos españoles de investigación en el área cardiovascular. Rev Esp Cardiol. 2002;55:900-12.
7. Miguel-Dasit A, Martí-Bonmati L, Aleixandre R, Sanfeliu P, Valderrama JC. Producción española sobre diagnóstico por la imagen en cardiología y radiología (1994-1998). Rev Esp Cardiol. 2004;57:806-14.
8. Boletín Oficial del Estado. ORDEN de 7 de noviembre, por la que se establecen las bases y se hace pública la convocatoria de concesión de ayudas para la realización de proyectos de investigación en el marco de algunos Programas Nacionales del Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica 2004-2007. BOE n.º 270, de 11 de noviembre de 2003. p. 39844-88.
9. Ministerio de Sanidad y Consumo. Instituto de Salud Carlos III. Redes Temáticas de Investigación Cooperativa Sanitaria [accedido 30 Nov 2005]. Disponible en: www.retics.net.
10. Boletín Oficial del Estado. Orden de 22 de marzo, por la que se convoca la concesión de ayudas para el desarrollo de Redes Temáticas de Investigación Cooperativa. BOE n.º 80, de 3 de abril de 2002. p. 12742-6.
11. Ministerio de Sanidad y Consumo. Instituto de Salud Carlos III. Subdirección General de Redes y Centros de Investigación cooperativa. Centro de investigación biomédica en red Ciber [accedido 30 Nov 2005]. Disponible en: www.isciii.es/htdocs/redes/ciber.jsp.
12. Newman MEJ. Coauthorship networks and patterns of scientific collaboration. Proc Natl Acad Sci USA. 2004;101:5200-5.
13. Barabásis AL, Jeong H, Néda Z, Ravasz E, Dchubert A, Vicsek T. Evolution of the social network of scientific collaborations. arXiv:condmat/0104152 10 abril 2001 (última revision 16/9/2005) [accedido 30 Nov 2005]. Disponible en: arxiv.org/PS_cache/cond-mat/pdf/0104/0104162.pdf.
14. Van Raan AFJ. Evaluación de la excelencia científica de programas de investigación: un punto primordial en la toma de decisiones. The IPTS Report 1999; 40 [accedido 24 Nov 2005]. Disponible en: www.jrc.es/home/report/spanish/articles/vol40/RTD5S406.htm.
15. Ministerio de Sanidad y Consumo. Centros y Servicios del Sistema Nacional de Salud [accedido 8 Feb 2006]. Disponible en: http://www.msc.es/ciudadanos/prestaciones/centrosServiciosSNS/home.htm.
16. Ministerio de Educación y Ciencia. Registro Nacional de Universidades, Centros y Enseñanzas [accedido 8 Feb 2006]. Disponible en: http://www.mec.es/educa/jsp/plantilla.jsp?area=ccuniv&id=802.
17. Álvarez C, Serna M, Díaz J. Modelos de grafos para la web. En: Martinón A, editor. Las matemáticas del siglo XX: una mirada en 101 artículos. Madrid: Nívola; 2000. p. 477-80.
18. Camí J, Suñén E, Méndez-Vázquez R. Caracterización bibliométrica de grupos de investigación biomédica en España [accedido 23 Nov 2005]. Disponible en: www.isciii.es/paginas/fis/mapa/index.htm.
19. Zulueta MA, Cabrero A, Bordons M. Identificación y estudio de grupos de investigación a través de indicadores bibliométricos. Rev Esp Doc Cient. 1999;22:333-47.
20. Sanz Menénez L. Análisis de redes sociales: o cómo representar las estructuras sociales subyacentes. Apuntes de Ciencia y Tecnología. 2003;7:21-9.
21. Universidad Complutense de Madrid. TextToPajek [accedido 20 Sept 2005]. Disponible en: http://www.ucm.es/info/pecar/Software.htm#textopajek.
22. PAJEK: Program for large network analysis [accedido 20 Sept 2005]. Disponible en: http://vlado.fmf.uni-lj.si/pub/networks/pajek.
23. Aleixandre R, Valderrama JC, Castellano M, Miguel-Dasit A, Simó R, Navarro C. Factor de impacto nacional e internacional de Revista Española de Cardiología. Rev Esp Cardiol. 2004;57:1241-4.
24. Price DJS. Networks of scientific papers. Science. 1965;149:510-5.
25. Bordons M, Gómez I. Collaboration networks in science. En: Cronin B, Atkins HB, editors. The web of Knowledge: a festschrift in honor of Eugene Garfield. Medford: Information Today; 2000. p. 197-213.
26. Weeks WB, Wallace AE, Kimberly BCS. Changes in authorship patterns in prestigious US medical journals. Soc Sci Med. 2004; 59:1949-54.
27. Agulló A, Aleixandre R. Evolución del índice de colaboración de los artículos médicos españoles en la presente centuria. Pap Med. 1999;8:16-20.
28. Bhopal R, Rankin J, McColl E, Thomas L, Kaner E, Stacy R, et al. The vexing question of authorship: views of researchers in a british medical faculty. BMJ. 1997;314:1009-12.
29. Scott T. Changing authorship system may be counterproductive. BMJ. 1997;315:744.
30. Cunningham SJ, Dillon SM. Authorship patterns in information systems. Scientometrics. 1997;39:19-27.
31. Guardiola E, Baños JE. Difusión internacional de la investigación española en algología. Análisis del período 1981-1990. Rev Esp Anestesiol Reanim. 1993;40:191-5.
32. Aleixandre R, Porcel A, Agulló A, Marset S, Abad F. Diez años de la revista Atención Primaria (1984-1993). Análisis bibliométrico y temático. Aten Primaria. 1996;17:225-30.
33. López-Briz E, Martí-Bonmatí E, Cervera P, Barreda A, Guevara J, Blasco I. La farmacia hospitalaria en España vista a través de tres revistas de la especialidad. Farm Clin. 1990;7:560-70.
34. Valderrama JC. Estudio bibliométrico de las publicaciones españolas sobre Drogodependencias en Medicina (1989-1994). Valencia: Universitat de València; 2000.
35. Guerra L, Parras F, Jaén P, Aleixandre R, Valderrama JC. Investigación española sobre VIH/SIDA. Madrid: Ministerio de Sanidad y Consumo; 1996.

36. Fariña LA. El número de autores en Actas Urológicas Españolas. Actas Urol Esp. 1996;20:194-8.
37. Fenning TM. Fraud offers big rewards for relatively little risk. Nature. 2004;427:393.
38. Relman AS. Responsabilities of authorship: where does the buck stop? N Engl J Med. 1984;310:1048-9.
39. Rennie D. Guarding the guardians: a conference on editorial peer review. JAMA. 1986;256:2391-2.
40. Comité Internacional de Editores de Revistas Médicas. Requisitos de uniformidad para los manuscritos enviados a revistas biomédicas: escritura y proceso editorial para la publicación de trabajos biomédicos. Rev Esp Cardiol. 2004;57:538-56.
41. Smith R. Should the criteria for autorship of scientific papers be changed? Yes: It is time to abandon autorship. CBE Views. 1997;10:133-4.
42. Horton R. The signature of responsibility. Lancet. 1997;350:5-6.
43. Smith R. Authorship is dying: long live contributorship. BMJ. 1997; 315:696.