# Coauthorship Networks and Institutional Collaboration in *Farmacia Hospitalaria*

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## Abstract

**Background:** Scientific collaboration is necessary for the advance of science. The purpose of this study is to analyze collaboration between authors and Spanish institutions in scientific studies published in *Farmacia Hospitalaria*, applying methodology derived from the analysis of social networks.

**Methodology:** The study identified pairs of authors and institutions co-authoring or co-signing the same works published in *Farmacia Hospitalaria* between 1998 and 2007, building collaboration networks using the TextToPajek and Networks-PAJEK programs.

**Results:** 448 articles were analyzed, showing an average signature/article index of 4.79. Applying a collaboration threshold of 3 articles, 26 clusters were formed with principal researchers being Jiménez Torres and Pérez Ruixo (n=16 co-authorships) and Ribas Sala and Codina Jané (n=15). Among the institutions, there was significant collaboration between the Complejo Hospitalario Virgen del Rocío and the Complejo Hospitalario Nuestra Señora del Valme (n=4), both in Seville, and between Hospital Vall d'Hebron (Barcelona), the Hospital de Navarra, and the Universitat de Barcelona (n=4).

**Discussion:** Analysis of the collaboration networks in *Farmacia Hospitalaria* has made it possible to identify the groups of authors and institutions in the area, as well as their relationships in terms of research and scientific publications. We propose to analyze the changes in these groups over a period of time, as well as to identify collaboration patterns in other national and international journals.

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An abbreviated, non-published version of this study was presented in the Conference of the Andalusian Society of Pharmacists from Hospitals and Health Centers held in Seville, April 24-26, 2008.

*Received:* Juny 11, 2008. *Accepted for publication:* Juny 23, 2008.

**Key words:** Scientific journals. Scientific collaboration. Coauthorship analysis. Collaboration networks. *Farmacia Hospitalaria*.

## Redes de coautorías y colaboración institucional en Farmacia Hospitalaria

**Introducción:** La cooperación científica es necesaria para el progreso de la ciencia. El objetivo de este estudio es analizar la colaboración entre los autores e instituciones españolas en los trabajos científicos publicados en Farmacia Hospitalaria, para lo cual se han aplicado metodologías procedentes del análisis de redes sociales.

**Métodos:** Se han identificado las coautorías o firmas conjuntas de pares de autores e instituciones de un mismo trabajo publicado en Farmacia Hospitalaria durante la década 1998-2007, construyendo las redes de colaboración mediante los programas TextToPajek y Networks-PAJEK.

**Resultados:** Se han analizado 448 artículos en los que el valor medio del índice firmas/trabajo ha sido 4,79. Con un umbral de colaboración de 3 artículos, se conforman 26 grupos que tienen como investigadores centrales a Jiménez Torres y Pérez Ruixo (n = 16 coautorías) y a Ribas Sala y Codina Jané (n = 15). En las instituciones destaca la colaboración entre el Complejo Hospitalario Virgen del Rocío y el Complejo Hospitalario Nuestra Señora de Valme (n = 4), ambas de Sevilla, y el Hospital Vall d'Hebron (Barcelona) con el Hospital de Navarra y la Universitat de Barcelona (n = 4).

**Discusión:** El análisis de las redes de colaboración en Farmacia Hospitalaria ha permitido identificar a los grupos de autores e instituciones del área y sus relaciones desde el punto de vista de la investigación y las publicaciones científicas. Se propone analizar los cambios en estos grupos a lo largo del tiempo, así como identificar los patrones de colaboración en otras revistas nacionales y extranjeras.

**Palabras clave:** Revistas científicas. Colaboración científica. Análisis de coautorías. Redes de colaboración. Farmacia Hospitalaria.

## INTRODUCTION

Scientific collaboration is necessary for the advance of knowledge, as solving problems requires multidisciplinary approaches and scientists who combine efforts to compensate for insufficiencies.[1,2] An aspect of collaboration among professionals which is most directly related to research is manifested as shared scientific publications.

Bibliometric indicators based on analysis of collaboration in scientific publications identify and characterize research groups and networks formed, and therefore contribute complementary information to that derived from other indicators and other possible cooperative structures which may form these groups.[3-5]

Through maps and coauthorship networks, some bibliometric techniques allow groups and research networks which emerge in publications from their combined efforts to be represented. In these networks, the most active group of researchers constitutes the forefront of the research area, receives scientific credit, and benefits from their position with funds granted for backing research. The forefront is not formed by individual authors, rather by collaborators, and additionally, these can establish collaborative relationships with other related research groups.[1] These techniques allow for quantification of the number of members making up the network, the relationship strength existing between them, and the most relevant members, based on a broad collection of measurements or indicators.[6,7] Analysis has been applied to a few Spanish biomedical areas, such as drug dependence,[3] cardiology,[6] and neurology,[7] and internationally, reproductive biology[8] and consumption of anabolic steroids,[9] which has allowed the most active research groups of each area to be identified.

The objective of this study was to analyze collaboration among Spanish authors and institutions in scientific studies published in *Farmacia Hospitalaria* from 1998-2007, by applying methodologies from social network analysis.

## METHODOLOGY

### Identification and Selection of the Studies

The articles published from 1998-2007 were identified in the journal *Farmacia Hospitalaria.* These studies were strictly selected for our study, and are those from the sections Original articles, Special article, Review, and Brief review. The contributions from the sections Editorial, Letters to editor, Acknowledgments, and Interviews were excluded.

### Selection of Bibliographic Information and Standardization of Authors' Names

The data for carrying out the study were drawn from the IME (Spanish Medical Index) database and compared with those from the journal's web page (http://www.sefh.es/01rvfh.php), where the full articles can be accessed free of charge. For each study selected, the name and surname of signing authors were identified, along with their origin (institution, city, and country).

The authors' names were standardized by unifying signatures where one author signed in 2 or more different ways (ie, with 1 or 2 surnames, a simple or compound name, with linguistic variations of the same name, with or without a dash between names) and by using the coincidence of both signatures being used in the work place as basic unification criteria.

For standardizing institutions, the different variations of hospitals and health centres were unified by using designations collected from the National Catalogue of Hospitals of the Ministry of Health and Consumption,[10] and regarding academic institutions, the National Registry of Universities, Centres, and Teaching of the Ministry of Education and Science were used.[11]

### Bibliometric Indicators of Collaboration and Coauthorship Networks

Global characterization of collaboration among authors was made effective by the collaboration index or signatures/work index, and regarding institutions, the number of documents signed in institutional collaboration was determined.

For identifying *clusters* or groups of authors and institutions, and analysis of social networks, all combinations of pairs of authors or coauthorships, were identified in each study. The term coauthorship refers to the joint signature of 2 authors in one scientific study. The term *cluster* refers to the collection of nodes and vertices (in our case, authors) highly connected between each other through arcs and links (coauthorship relationships). Threshold and strength of collaboration is the value used to form groups of authors and refers to the frequency of coauthorship between pairs of authors. It more or less reflects the consolidated relationships between them when co-publishing research results, and bibliometric studies are used as criteria for determining those research groups.[12,13]

Once the number of various coauthorships was quantified, an algorithm was applied to consider the existence of a *cluster* or group of authors, when at least 2 connected authors were identified with a certain number of co-signed studies, or coauthorships. This minimum number of coauthorship studies is fixed a priori by the threshold of applied collaboration.

Given the impossibility of graphically representing all existing relationships which emerge by applying different thresholds, the collaboration threshold was decided at ≥3 co-published articles to build groups of authors, and a collaboration threshold of ≥2 articles to build groups of institutions; in this way, the groups may be illustrated with greater clarity.

For characterizing institutional collaboration, centrality indicators were calculated which facilitated knowledge of the degree of interconnection between institutions and the overall position they hold within the network. The range or (*degree*) of centrality is the number of nodes to which an institution is connected, or the different number of institutions with whom they have collaborated. The degree of (*betweenness*) indicates the frequency with which

a node appears in the shortest stretch connecting 2 other nodes, or this is a measurement which quantifies if an institution acts as an intermediary and allows for connection between others while "bridging" 2 others in the evaluation of their standing, and capacity for access and control of information flow. The (*closeness*) indicator measures the capacity and proximity of a node to reach the rest of the nodes which make up the network, allowing for assessment of the interaction speed of an agent with the other agents of the network.[14,15]

Microsoft Office Access for Windows and Pajek software for analysis and visualization of networks were used[16] to manage all the information, and calculate bibliometric indicators and social networks, along with building graphical illustrations of groups of authors and institutions.

## RESULTS

Four hundred forty-eight published articles were used from *Farmacia Hospitalaria* from 1998-2007 (Table 1). The number of published articles per year was consistently around 45, along with the signatures/study index, whose average value for the whole period was 4.79, reaching its highest values at the start and end. This value is quite similar to the 4.6 found by Ferriols et al (2007) from 2001-2006 in this same journal. The 448 articles comprise 2147 signatures.

The number of groups and authors which comprise these articles can be seen in Table 2. When applying threshold or collaboration strength for 5 or more coauthored studies (n≥5), 7 groups were identified, which made up 20 authors. If the collaboration threshold is established at 4 or more co-authored studies, 47 authors constitute 16 groups, and if the threshold is established at 3 articles, 107 authors constitute 26 groups. As previously mentioned, the latter threshold was used in this study to graphically represent the groupings and can be observed in Figure 1 A and B. Of the 26 groupings, 2 are made up of 9 authors, 2 have 8, one has 7, and the remaining 21 have less than 7 authors. The first group with 9 authors has Ribas Sala and Codina Jané as principal researchers (from Hospital Clínic i Provincial of Barcelona), with 15 co-authored articles, and the second group's principal researchers are Jiménez Torres and Pérez Ruixo (from Hospital Doctor Peset of Valencia), with 16 co-authored articles. In the 8 author groups, the strongest relationship was between Navarro Ruiz and Borrás Blanco (from Hospital General Universitario of Elche), with 10 co-authored articles, as well as between Navarro Ruiz and González Delgado, and the second was with Borrás Blasco (with 8 co-authored articles, each with a different co-signer), all of them were also from the Hospital General Universitario of Elche. These 3 groups were those with the most components, or those with the most authors constituting the group, and were also the groups with the most coauthorship activity. In the groups with fewer components, the strongest coauthorship (5 co-authored studies) corresponded to the pairs Herreros de Tejada and Campo Angora; Faus Soler and Soler Company; Pla Poblador and Garriga Biosca; and lastly, Mariño Hernández and Modamio Charles (Figure 1b).

With respect to the research institutions of authors (Table 3), a coauthorship threshold of at least 2 co-published studies pertained to 6 groups comprising 46 institutions, where a group of 34 institutions stood out which integrated numerous hospitals from all over Spain with little collaborative strength. The maximum degrees of coauthorship were established in 4 studies between the Complejo Hospitalario Virgen del Rocío and the Complejo Hospitalario Nuestra Señora de Valme, both from Seville, and the Hospital Vall d'Hebron (Barcelona) with the Hospital de Navarra and the Universitat of Barcelona. However, the maximum coauthorship was established in a group of 4 institutions between the Universitat of Valencia and the Hospital Universitario Doctor Peset, with 19 co-authored articles (Figure 2).

**Table 1.** Number of Published Documents and Annual Collaboration of Authors in *Farmacia Hospitalaria* (1998-2007)

| Year | No. of Documents | No. of Signatures | Index of Signatures/ Study |
|---|---|---|---|
| 1998 | 45 | 234 | 5.20 |
| 1999 | 45 | 200 | 4.44 |
| 2000 | 51 | 234 | 4.59 |
| 2001 | 38 | 182 | 4.79 |
| 2002 | 37 | 154 | 4.16 |
| 2003 | 41 | 199 | 4.85 |
| 2004 | 58 | 286 | 4.93 |
| 2005 | 45 | 217 | 4.82 |
| 2006 | 45 | 221 | 4.91 |
| 2007 | 43 | 220 | 5.12 |
| Total | 448 | 2147 | 4.79 |

**Table 2.** Identification of Groups of Authors in Studies Published in *Farmacia Hospitalaria* (1998-2007)

| Strength of Collaboration[a] | Authors | | | |
|---|---|---|---|---|
| | No. of Groups | No. of Authors in the Groups | Size of the *Cluster* With the Greatest No. of Authors[b] | Index Authors/ Group[c] |
| ≥ 5 | 7 | 20 | 4 | 2.86 |
| ≥ 4 | 16 | 47 | 7 | 2.94 |
| ≥ 3 | 26 | 107 | 9 | 4.11 |
| ≥ 2 | 53 | 327 | 40 | 6.17 |

[a]Minimum number of co-authored studies needed for a collaboration link to be considered between them. High collaboration strengths reflect consolidated connections, and as this value descends, it produces the phenomenon known in the theory of networks as "percolation effect," where an increasing number of agents become interconnected.
[b]Collection of agents (authors) interconnected directly or through intermediaries. In the theory of networks "giant component" is designated.
[c]Index which correlates the number of authors with the number of groups identified, showing the average value the groups' size.

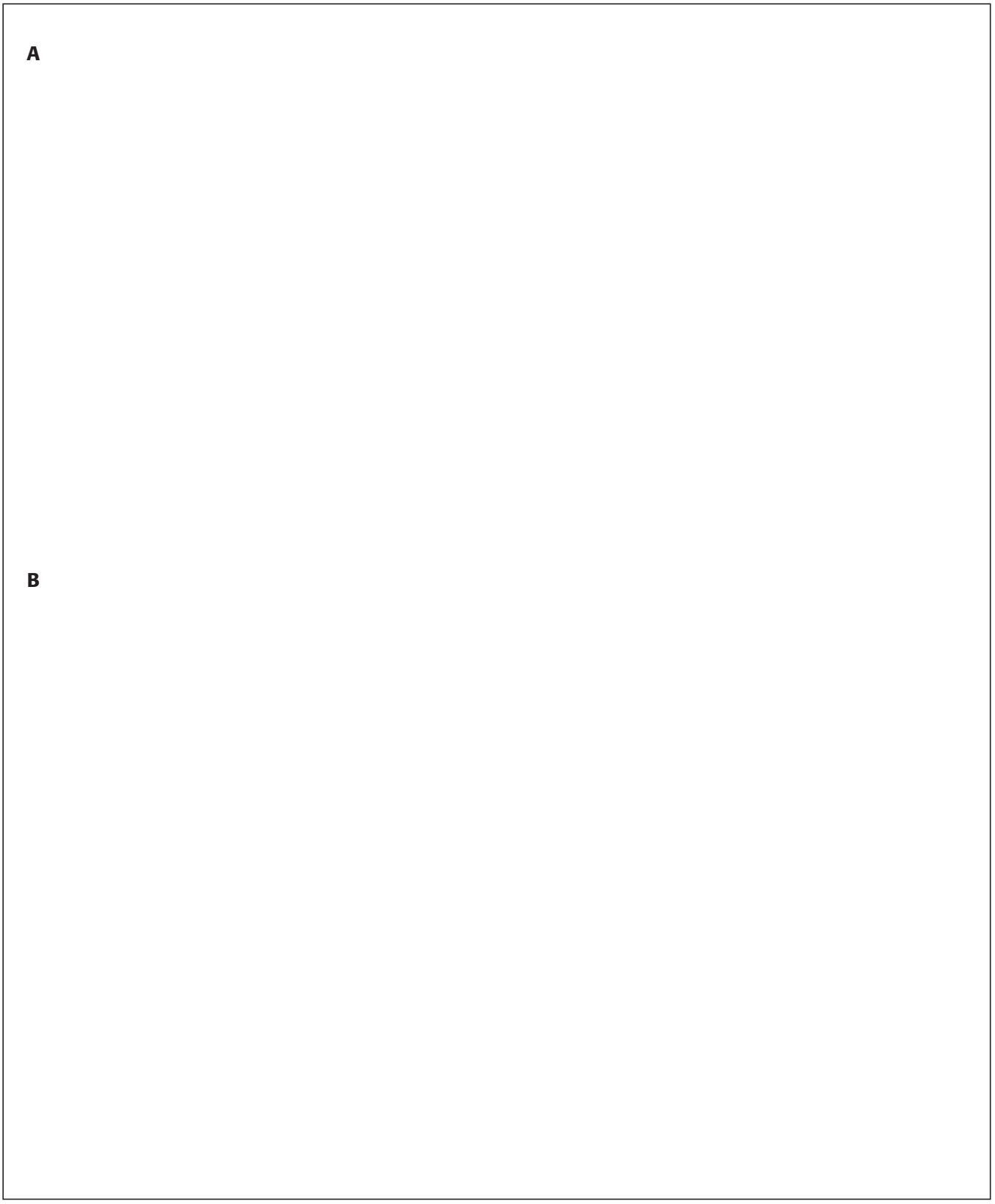


***Figure 1.*** *Principal groups of authors (≥3 co-authored documents) identified in* Farmacia Hospitalaria *(1998-2007).*[a]
[a]*Groups built based on coauthorships or co-signings of authors in scientific studies. Strength of collaborations (coauthorship of a specific number of studies) is reflected by the number placed on the lines or links between authors.*

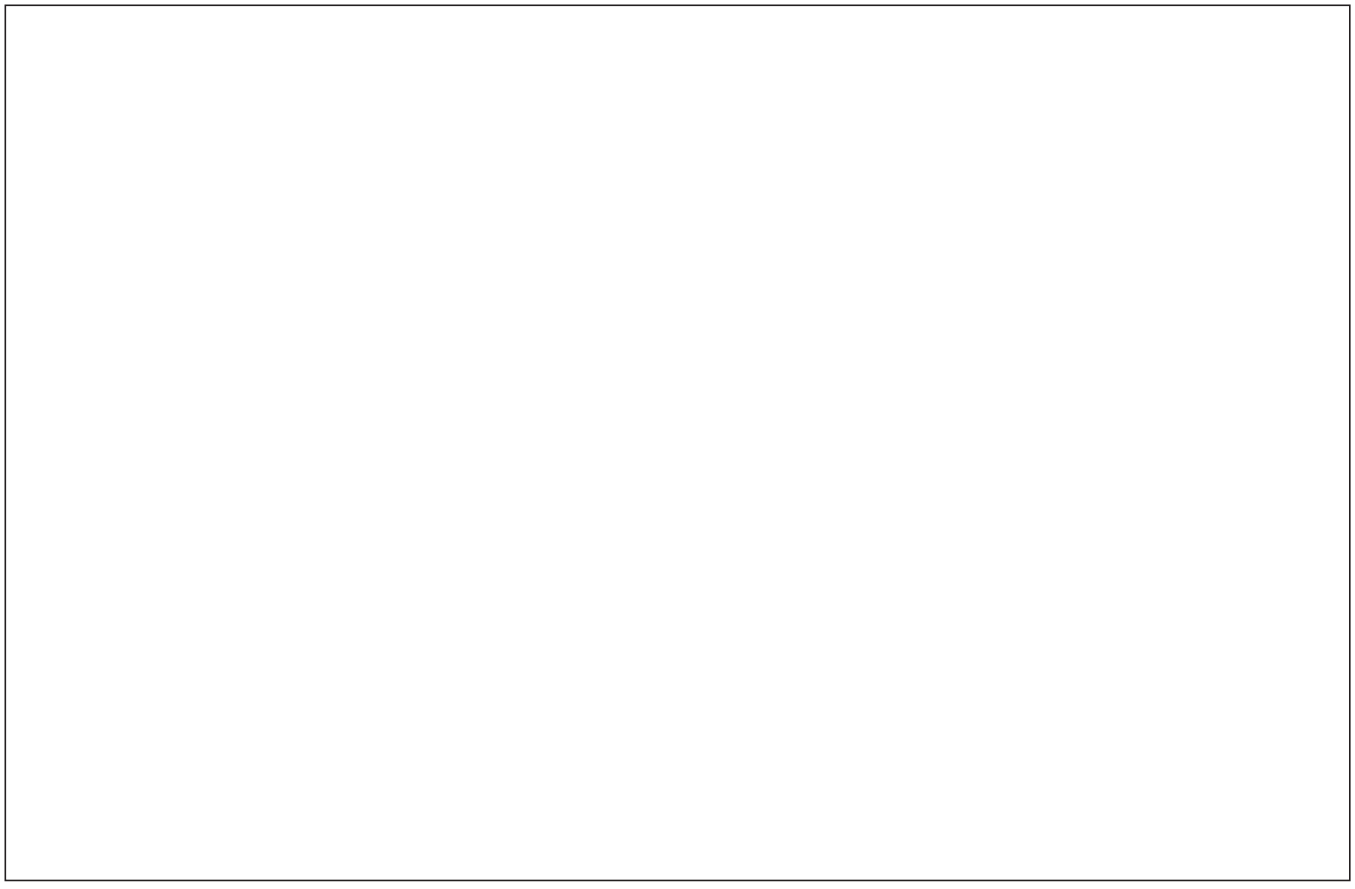

***Figure 2.*** *Principal nucleus of institutional collaborations network (≥2 collaborated documents) identified in* Farmacia Hospitalaria *(1998-2007).*[b] [b]*Network built based concurrence of centres with institutional affiliations of scientific studies. The nuclei which form symmetrical polyhedrons reflect higher density collaborations in scientific studies among groups of institutions, a reason why they are very united and consolidated nuclei. The strength of collaborations (coauthorship in a determined number of studies) is reflected by the number placed on the lines or links between institutions.*

The indicators from the social network analysis which characterize institutional collaboration (degree of interconnection among institutions, degree of intermediation, and closeness) are presented in Table 4. The maximum degree values were obtained by the Hospital Vall d'Hebron and the Hospital 12 de Octubre (degree=10), while the maximum for intermediation and closeness corresponded to the Hospital Clínic i Provincial of Barcelona, followed by the Hospital Severo Ochoa in Oviedo.

## DISCUSSION

One of the main challenges left for science is to prompt scientific cooperation, both nationally and internationally, through the creation of collaboration networks between researchers. The importance which administrative organizations of scientific policies grant to scientific collaboration is reflected in numerous initiatives where cooperation and association between scientific groups and research centres is sought to be fostered. In Spain, from 2004-2007, the National Plan for Scientific Research, Development, and Technological Innovation sought to promote multidisciplinary research through the Carlos III Health Institute, by way of measures taken for the creation of stable structures for cooperative research. Among these were, Specialty Networks for Cooperative Research (RETIC)[17] and Networks of Biomedical Research Centres (CIBER),[18] research organizations with own legal status whose task is monographic research of a disease or particular health problem, and these will constitute large centres of transferable research. In the European Union the actions of the European Cooperation in the Field of Scientific and Technical Research (COST)[19] should be mentioned, among others.

With this classification of networks, the creation of more powerful strategies for scientific cooperation allowing goals to be achieved which could be proposed with difficulty in more restricted circumstances of implementation. Within these initiatives, specific groups from hospital pharmacy have not been found, this however does not rule out the possibility that field specialists may be involved in networks of other specialties or even multidisciplinary ones.

Bibliometric indicators and analysis of social networks applied to collaboration in scientific publications allow identification of

**Table 3.** Identification of Groups of Institutions in Studies Published in *Farmacia Hospitalaria* (1998-2007)

| Strength of Collaboration[a] | Authors | | | |
|---|---|---|---|---|
| | No. of Groups | No. of Institutions in the Groups | Size of Group With the Greatest No. of Institutions[b] | Index Institutions/ Group[c] |
| ≥5 | 1 | 4 | 4 | 4 |
| ≥4 | 3 | 9 | 4 | 3 |
| ≥3 | 6 | 21 | 6 | 3.5 |
| ≥2 | 6 | 46 | 34 | 7.67 |

[a]Minimum number of studies which institutions needed to co-publish for a collaboration link to be considered between them. High collaboration strengths reflect consolidated connections, and as this value descends, it produces the phenomenon known in the theory of networks as "percolation effect," where an increasing number of agents become interconnected.
[b]Collection of agents (institutions) interconnected directly or through intermediaries. In the theory of networks "giant component" is designated.
[c]Index which correlates the number of institutions with the number of groups identified, and shows the average value groups' size.

the principal research groups and networks that are generating scientific output beyond the available formal cooperative structures. One of the benefits from this type of analysis for professionals is that it makes dependable information available to them on already existing research groups, allowing them to possibly join identified networks and increase their capabilities, or broaden their circle of scientific contacts and participate more broadly in discussion forums and exchange ideas on interesting issues of their corresponding areas. On the other hand, it allows for knowledge of existing connections between centres (what institutions collaborate between each other, who occupies the most central positions or are the most noteworthy, and who remains on the periphery), constituting highly valuable information for analyzing the degree of efficiency of resources directed for collaborative research and may be useful for making funding decisions for consolidated or emerging specialty networks.

In comparison with other journals analyzed,[3,6,7] *Farmacia Hospitalaria* gathers fewer authors and groups of high strength collaboration researchers than other journals, such as *Revista de*

**Table 4.** Principal Agents of the Institutional Collaborations Network of Studies Published in *Farmacia Hospitalaria* (1998-2007)[a]

| Degree | | Intermediation x 100 | | Closeness x 100 | |
|---|---|---|---|---|---|
| Institution | Value | Institution | Value | Institution | Value |
| Hospital Vall d'Hebron | 10 | Hospital Clínic i Provincial de Barcelona | 0.0060284 | Hospital Clínic i Provincial de Barcelona | 0.0575385 |
| Hospital 12 de Octubre | 10 | Hospital Severo Ochoa | 0.0056549 | Hospital Severo Ochoa | 0.0568101 |
| Hospital General de Castelló | 8 | Hospital 12 de Octubre | 0.0054929 | Complejo Hospitalario Virgen del Rocío | 0.0554074 |
| Hospital de Navarra | 8 | Hospital Vall d'Hebron | 0.0047426 | Hospital 12 de Octubre | 0.0534286 |
| Hospital Universitario de Bellvitge | 7 | Hospital General de Castelló | 0.0038541 | Complejo Asistencial de Salamanca | 0.0528000 |
| Complejo Hospitalario Universitario de Albacete | 7 | Complejo Hospitalario Virgen del Rocío | 0.0037311 | Hospitals Vall d'Hebron | 0.0515862 |
| Universidad Pompeu Fabra | 6 | Complejo Asistencial de Salamanca | 0.0031222 | Sociedad Española de Farmacia Hospitalaria | 0.0498667 |
| Universitat de Barcelona | 6 | Hospital de Navarra | 0.0027821 | Hospital de Navarra | 0.0493187 |
| Sociedad Española de Farmacia Hospitalaria | 6 | Sociedad Española de Farmacia Hospitalaria | 0.0024042 | Hospital Ramón y Cajal | 0.0472421 |
| Hospital Universitario Germans Trias i Pujol | 6 | Hospital Universitari de Bellvitge | 0.0010364 | Instituto Oncologico de San Sebastián | 0.0453333 |
| Hospital Clínic i Provincial de Barcelona | 6 | Hospital Clínico Universitario | 0.0010364 | Hospital General de Castelló | 0.0444356 |
| Complejo Hospitalario Virgen del Rocío | 6 | Complejo Hospitalario Universitario de Albacete | 0.0010364 | Hospital del Mar | 0.0440000 |
| Pharmacoeconomics & Outcomes Research Iberia | 5 | Hospital Ramón y Cajal | 0.0008583 | Pharmacoeconomics & Outcomes Research Iberia | 0.0427429 |
| Hospital Ramón y Cajal | 5 | Universitat de València | 0.0000648 | Hospital de Galdakao-Usansolo | 0.0427429 |
| Hospital de Galdakao-Usansolo | 5 | Rest of Institutions | 0 | Complejo Asistencial de León | 0.0427429 |
| Complejo Asistencial de León | 5 | – | – | Hospital Universitari de Bellvitge | 0.0408000 |
| 30 institutions with 1-4 | 1-4 | – | – | Complejo Hospitalario Universitario de Albacete | 0.0408000 |

[a]In this table, a few of the measurements used in the literature on networks is collected for determining the position the agents (institutions) take in the overall network. The degree is the number of different institutions with which a centre has collaborated. It is a measurement which reflects the size of the circle of collaborators of the institution and is a statistic which positively assesses collaboration compared to other bibliometric indicators based on the number of studies or scientific productivity. Intermediation is the frequency that an institution appears in the shortest stretch linking two other institutions. This statistic evaluates institution's centrality, and is related to its capacity for accessing and controlling information flow. Closeness is the inverse of the sum of distances between an institution and the rest of institutions to which it is connected. This is a statistic which assesses the centrality of the institution based on its proximity to the rest of the institutions forming the network.

*Neurología* and *Revista Española de Cardiología* (45 compared with 25 groups, respectively, by applying a collaboration threshold of 6 or more articles), and fewer in other areas, such as drug dependence (with 18 groups of authors in studies published in Spanish journals and 20 groups in foreign journals). In reference to indicators which characterize institutional collaboration (degree, intermediation, and closeness), there are also differences from other areas. While in *Farmacia Hospitalaria* maximum degree values correspond to the Hospital de Vall d'Hebron and Hospital 12 de Octubre, in *Revista Española de Cardiología* and *Revista de Neurología* these correspond to Hospital Universitario de La Fe (Valencia). With respect to intermediation and closeness, this latter hospital takes the first place in *Revista Española de Cardiología*, while in *Revista de Neurología* the greatest intermediation corresponds to the Universidad Autonoma of Madrid and to the Complejo Hospitalario Universitario Virgen del Rocío, and the greatest closeness to the Hospital de Vall d'Hebron.[6,7]

The presence in *Farmacia Hospitalaria* of numerous groups and a reduced number of researchers included in some of the groups can be explained by the existence of numerous research groups which are emerging and lack the necessary cohesion between each other and have few connections with other groups. Research in Spanish hospital pharmacy is in the beginning of its development, as it is a new specialty where the majority of health services depend on emerging research groups who are not consolidated. Otherwise, cooperative and multicentric research has great potential.[20]

The pattern of collaboration among institutions observed in this study is related to the Spanish research system, where hospital pharmacy principally functions in health centres (mostly hospitals), and likewise, other types of centres have emerged in the groupings, such as universities (Valencia, Zaragoza, and Federal de Bahía).

Pharmaceutical companies such as Aventis, Johnson & Johnson Pharmaceutical Research & Development, Pharmacoeconomics & Outcomes Research Iberia, and Pfizer are also an interesting presence.

For years, the disintegrated diachronic evolution of the collaboration index has remained practically constant at around 5 authors per study. This index is very similar to that found by Ferriols et al[21] in the period from 2001-2006 (4.6), but less than that observed in journals of other specialties, such as *Revista Española de Cardiología (*6.23).[6]

In reference to collaboration among health centres, it has been shown that the strongest collaborative relationships are developed between internally connected institutions (such as hospitals connected with universities) or by geographical proximity (ie, centres of the same city or autonomous community), and by the reduced inconvenience of international collaboration.

Regarding this study's limitations, it should be mentioned that this study only analyzes collaboration patterns of authors who publish in one journal, *Farmacia Hospitalaria*. To gain a fuller insight into collaboration in the area of hospital pharmacy, studies on this issue which are found in journals of other scientific areas, both nationally and internationally, should be analyzed. Nevertheless, this study comprises a good approximation to the analysis of collaboration and of existing research groups in this specialty, because the journal analyzed has broad circulation in national and foreign databases, and furthermore, its bibliometric indicators have developed positively in recent years.[20,21-23] In a recent study, the journal's progress and national impact factor was shown, and had increased 0.485 points from 2001-2005. This impact was greater than other pharmacological and related journals analyzed, practically equaling that of *Revista Española de Quimioterapia* but adequately surpassing them in terms of developmental tendency. The international impact factor placed the journal above other journals of the field, such as *Pharmacology & Pharmacy* of Journal Citation Reports.[6]

On the other hand, it is important to highlight that analyses of social networks of health sciences based on collaborative studies carried out is in its emergence, as uniform criteria still have not been established which allow for identification and characterization of communities or research groups existing within previously built networks, nor comparisons with previous similar studies.

Future lines of research should identify networks and groups which are established when analyzing all national and foreign journals of the research area, such as their visibility and scientific impact (measured by the number of citations received), specialty areas of research of the groups identified, and the quality or scientific excellence of studies published. Furthermore, given the dynamic character of science and research groups, it would be interesting to observe its development over time and analyze variations (growth, or decrease in the number of groups and members of each), such as the reason for there being "black holes" in networks, or authors or institutions which remain on the periphery or isolated from the network.

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