State of the art paper

Current status of global research on pericardial diseases: a bibliometric analysis of the top 100 from Web of Science

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Abstract

Introduction: Bibliometric studies can help guide researchers and funding bodies toward fields where more research activity is warranted. Bibliometric analyses have previously been published in many specialties and sub-specialties. Our literature search did not show a bibliometric analysis on pericardial diseases. We performed a bibliometric analysis of the top 100 cited manuscripts on pericardial diseases to identify knowledge.
Material and methods: Bibliometric analysis is a quantitative method to assess research performance and analyze publication trends. Web of Science was searched in April 2020 to identify the top 100 cited manuscripts in pericardial diseases.
Results: Twenty-six out of the top 100 cited manuscripts were published between 2000 and 2009. These manuscripts were cited on average189 times (range: 110–743) since publication. Only two manuscripts were cited > 500 times. Among the top-ten cited manuscripts, there were 6 original articles, 1 case series, and 3 review articles. Of the 3 review articles, 2 were society guidelines. 90% of the authors had written just 1 manuscript. There were ten manuscripts with women as first authors with a significant association between gender of the first and corresponding author (odds ratio = 44, $p < 0.001$). Only 20% of manuscripts were funded. Most publications came from institutions in the United States ($n = 40$), Italy ($n = 10$), and Spain ($n = 5$).
Conclusions: Our study provides an insight into the characteristics and quality of the highly cited literature in the field of pericardial diseases. This can be used to guide further research in the field of pericardial diseases.

Key words: pericardial, bibliometrics, research output, clinical trial, women in cardiology.

Introduction

Pericardial diseases carry significant morbidity and mortality and their presentation can range from asymptomatic and transient to severe and recurrent forms which may be life-threatening [1]. Bibliometric analysis is a well-established quantitative method for assessing research performance that evaluates the pattern and frequency of occurrence of citations in literature [2–4]. Although it is difficult to evaluate the true value of an article, citation analysis allows us to identify landmark studies in a particular field, demonstrate knowledge gaps, and identify studies that may have had a disproportionate influence on a particular field [3, 4]. Bibliometric studies in medicine have helped identify focus areas and understand biases in scholarly output [5]. Considering the significant disease burden, prolonged course, as well as evolving treatment options, it is likely that the research interest in the field of pericardial diseases will continue to evolve. In an attempt to better understand the research output in pericardial disease in terms of focus areas, role of funding, female representation, and to guide future course, we conducted a bibliometric analysis of the top 100 cited manuscripts on pericardial diseases.

Material and methods

Search strategy

We searched Web of Science from inception (January 1900) to April 20, 2020, using the following search terms: "pericarditis", "pericardial", "pericardium", "pericardial effusion", and "tamponade". Under Web of Science Core Collection, the following data sources were selected that were pertinent to our study: Science Citation Index Expanded (SCI-EXPANDED), Conference Proceedings Citation Index- Science (CPCI-S), and Emerging Sources Citation Index (ESCI). From the search results, a list of journals under the Web of Science subject categories "Cardiac Cardiovascular System", "Medicine General Internal", "Oncology", "Surgery", "Immunology", "Radiology Nuclear Medical Imaging", and "Pathology" was compiled. This was done to avoid missing out on articles on pericardial disease that were published in journals other than those that focused on cardiovascular diseases only. These journals were then searched to compile a database of manuscripts pertaining to pericardial diseases. Only English language studies in humans and the field of medicine were included. We excluded studies that were done on animals. All manuscripts from journals focusing on fields of science other than medicine were also excluded. We did not limit our search based on abstract availability, country of origin, or study type. All journals included in our list were searched using print and electronic International Standard Serial Numbers. For manuscripts where electronic copies were unavailable, hard copies were sought from an inter-library loan service to ensure that full texts of included articles were reviewed.

After an extensive search, the results were sorted in descending order of citations received. This method of citation analysis has been shown to be a reliable measure of assessing the impact of an article [4]. The title and abstracts were screened by 2 reviewers (V.J. and H.N.E.) independently to ensure that the manuscripts adhered to the aforementioned inclusion criteria. A list of the top 100 cited manuscripts was subsequently compiled. In case of discrepancy, a consensus was achieved with the help of a third independent reviewer (A.K.). This was a retrospective review of already published literature and institution review board approval was not required.

Study variables

Data were extracted regarding citation count, authors, institutional affiliation, country, year, journal of publication and theme. The bibliometric tags used for analysis from the Web of Science search are presented in Supplementary Table SI.

The manuscripts were ranked in order of total citations received since publication. The most relevant authors were defined by the number of manuscripts contributed by them in the top 100 list. While ranking authors on relevance, the order of authorship in the manuscript was not given weightage. For example, authors with the same number of manuscripts as the first or second author had the same relevance. We calculated a collaboration index for multi-authored (≥ 2) manuscripts. It is given as total authors/total multi-authored manuscripts [6]. The collaboration index helps understand the mean number of authors per multi-authored manuscript, with a higher collaboration index implying more collaboration among authors. The reprint author was designated as the corresponding author. This method has previously been validated in other bibliometric analysis [7]. If multiple authors were designated as corresponding authors, we considered all of them as corresponding authors. Information on the gender of the first and the corresponding author was extracted using the author's photograph on institutional portfolios. The relevance of institutions and countries was derived according to the number of manuscripts. If there were multiple authors on a manuscript with different institutional affiliations or countries, the document was assigned to > 1 institution or country. Thus, there could be more than 100 institutional affiliations. In cases where authors changed their affiliation over time, we selected the country and institute

with which the authors were affiliated at the time of publication of the respective manuscript.

We used Keywords Plus to identify keywords that are automatically generated from a manuscript's bibliography and are unique to the Web of Science [8]. Keywords Plus may include words not included in author keywords and help evaluate an article's content in greater depth. These were analyzed using a co-occurrence network to identify recurrent associations. The abstracts of the manuscripts were reviewed to identify themes.

Local citations are the manuscripts that are included in the bibliography of ≥ 1 manuscript in the reference set, i.e. manuscripts that were cited by the top 100 most cited manuscripts. We used reference publication year spectroscopy to create a temporal profile of these locally cited references in the top 100 cited manuscripts to understand the impact of landmark publications [9]. Landmark publications have been evaluated previously to assess the impact of key publications over time that were cited multiple times by the most impactful papers in a field. We considered the top 10% most locally cited publications as landmark publications [10].

Software for bibliometric analyses

The *bibliometrix* package of R statistical software was used for bibliometric analysis [11]. Briefly, *bibliometrix* is an open-source R package used for comprehensive science mapping using a logical bibliometric flow. It uses metadata from Web of Science references as bibliographic attributes and facilitates data analysis and data visualization.

We used the χ^2 test to evaluate an association between the gender of the first and the corresponding author. The statistical analyses were conducted in Stata version 14.2 (StataCorp, College Station, TX, U.S.A.). All *p*-values were 2-sided, with < 0.05 considered statistically significant.

Results

Citations and type of manuscript

Among the top 100 cited manuscripts in the Web of Science, there were 43 case series, 25 review papers, 14 cohort studies, 7 randomized trials, 5 cross-sectional studies, 4 case-control studies, and 2 meta-analyses. Of the review articles, 3 were society guidelines. These manuscripts were published between 1965 to 2015 in 29 sources and 26% of manuscripts were published between 2000 and 2009 (Supplementary Figure S1 A). The ten manuscripts with the highest number of citations are given in Figure 1. Among these ten manuscripts, there were 6 original articles, 1 case series, and 3 reviews. Of the 3 review articles, 2 were society guidelines. A complete list of the top 100 manuscripts is given in Table I. These manuscripts were cited 189 times on average (range: 110–743); only two manuscripts were cited > 500 times.

Authors

The top 100 manuscripts were published by 478 authors and 9 manuscripts were written by a single author. Each document was written by five authors on average with a collaboration index of 5.3. Around 90% of authors had written just one document. The most relevant authors are given in Table II and Supplementary Figure S1 B. Women were the first author in ten manuscripts and the corresponding author in seven manuscripts. There was a significant association between the gender of the first and the corresponding author, such that there were higher odds of having a woman as a first author if the corresponding author was also a woman (odds ratio = 44, $p < 0.001$).

Author affiliation, country and funding information

Harvard University and Mayo Clinic Foundation in the United States and Maria Victoria Hospital in Italy had the highest number of manuscripts in the top 100 (Supplementary Figure S1 C). Most manuscripts were from institutions in the United States (n = 40), Italy (n = 10), and Spain (n = 5). There were only a few manuscripts that had co-authors from multiple countries (Supplementary Figure S2). Funding information was publicly available for 20 manuscripts; thirteen were funded by US organizations – nine by the National

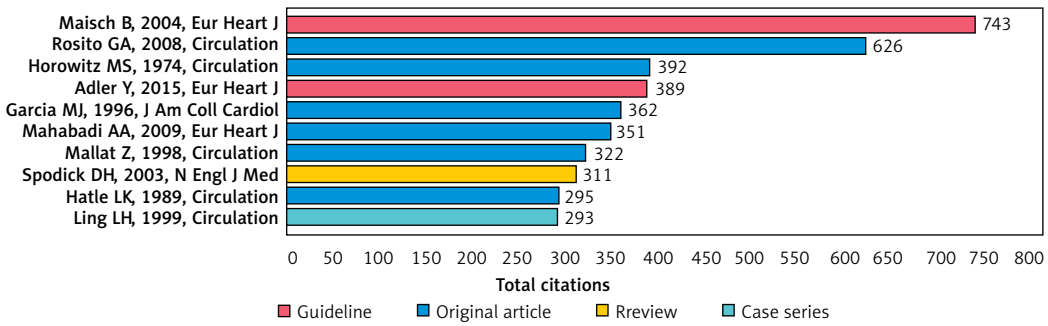

Figure 1. Top 10 most cited manuscripts on the pericardium

Table I. Top 100 cited documents in decreasing order of citations received

Document	Total citations	TC per year
Maisch B, Seferović PM, Ristić AD, Erbel R, Rienmüller R, Adler Y, Tomkowski WZ, Thiene G, Yacoub MH, Priori SG, Alonso Garcia MA. Guidelines on the diagnosis and management of pericardial diseases executive summary: the Task Force on the Diagnosis and Management of Pericardial Diseases of the European Society of Cardiology. European Heart Journal 2004; 25: 587-610.	743	43.71
Rosito GA, Massaro JM, Hoffmann U, Ruberg FL, Mahabadi AA, Vasan R. S, O'Donnell CJ, Fox CS. Pericardial fat, visceral abdominal fat, cardiovascular disease risk factors, and vascular calcification in a community-based sample: the Framingham Heart Study. Circulation 2008; 117: 605-13.	626	48.15
Horowitz MS, Schultz CS, Stinson EB, Harrison DC, Popp RL. Sensitivity and specificity of echocardiographic diagnosis of pericardial effusion. Circulation 1974; 50: 239-47.	392	8.34
Adler Y, Charron P, Imazio M, Badano L, Barón-Esquivias G, Bogaert J, Brucato A, Gueret P, Klingel K, Lionis C, Maisch B. 2015 ESC Guidelines for the diagnosis and management of pericardial diseases: the Task Force for the Diagnosis and Management of Pericardial Diseases of the European Society of Cardiology (ESC) Endorsed by: The European Association for Cardio-Thoracic Surgery (EACTS). European Heart Journal 2015; 36: 2921-64.	389	64.83
Garcia MJ, Rodriguez L, Ares M, Griffin BP, Thomas JD, Klein AL. Differentiation of constrictive pericarditis from restrictive cardiomyopathy: assessment of left ventricular diastolic velocities in longitudinal axis by Doppler tissue imaging. Journal of the American College of Cardiology 1996; 27: 108-14.	362	14.48
Mahabadi AA, Massaro JM, Rosito GA, Levy D, Murabito JM, Wolf PA, O'Donnell CJ, Fox CS, Hoffmann U. Association of pericardial fat, intrathoracic fat, and visceral abdominal fat with cardiovascular disease burden: the Framingham Heart Study. European Heart Journal 2009; 30: 850-6.	351	29.25
Mallat Z, Philip I, Lebret M, Chatel D, Maclouf J, Tedgui A. Elevated levels of 8-iso-prostaglandin F2αin pericardial fluid of patients with heart failure: a potential role for in vivo oxidant stress in ventricular dilatation and progression to heart failure. Circulation 1998; 97: 1536-9.	322	14.00
Spodick DH. Acute cardiac tamponade. New England Journal of Medicine 2003; 349: 684-90.	311	17.28
Hatle LK, Appleton CP, Popp RL. Differentiation of constrictive pericarditis and restrictive cardiomyopathy by Doppler echocardiography. Circulation 1989; 79: 357-70.	295	9.22
Ling LH, Oh JK, Schaff HV, Danielson GK, Mahoney DW, Seward JB, Tajik AJ. Constrictive pericarditis in the modern era: evolving clinical spectrum and impact on outcome after pericardiectomy. Circulation 1999; 100: 1380-6.	293	13.32
Shabetai R, Fowler NO, Guntheroth WG. The hemodynamics of cardiac tamponade and constrictive pericarditis. American Journal of Cardiology 1970; 26: 480-9.	290	5.69
Imazio M, Bobbio M, Cecchi E, Demarie D, Demichelis B, Pomari F, Moratti M, Gaschino G, Giammaria M, Ghisio A, Belli R. Colchicine in addition to conventional therapy for acute pericarditis: results of the COlchicine for acute PEricarditis (COPE) trial. Circulation 2005; 112: 2012-6.	272	17.00
Grebenc ML, Rosado de Christenson ML, Burke AP, Green CE, Galvin JR. Primary cardiac and pericardial neoplasms: radiologic-pathologic correlation. Radiographics 2000; 20: 1073-103.	271	12.90
Permanyer-Miralda G, Sagrista-Sauleda J, Soler-Soler J. Primary acute pericardial disease: a prospective series of 231 consecutive patients. American Journal of Cardiology 1985; 56: 623-30.	235	6.53
Troughton RW, Asher CR, Klein AL. Pericarditis. The Lancet 2004; 363: 717-27.	234	13.76
Lorell B, Leinbach RC, Pohost GM, Gold HK, Dinsmore RE, Hutter AM, Pastore JO, Desanctis RW. Right ventricular infarction: clinical diagnosis and differentiation from cardiac tamponade and pericardial constriction. American Journal of Cardiology 1979; 43: 465-71.	234	5.57
Tsang TS, Enriquez-Sarano M, Freeman WK, Barnes ME, Sinak LJ, Gersh BJ, Bailey KR, Seward JB. Consecutive 1127 therapeutic echocardiographically guided pericardiocenteses: clinical profile, practice patterns, and outcomes spanning 21 years. Mayo Clinic Proceedings 2002; 77: 429-436	227	11.95
Bertog SC, Thambidorai SK, Parakh K, Schoenhagen P, Ozduran V, Houghtaling PL, Lytle BW, Blackstone EH, Lauer MS, Klein AL. Constrictive pericarditis: etiology and cause-specific survival after pericardiectomy. Journal of the American College of Cardiology 2004; 43: 1445-52.	216	12.71

Table I. Cont.

Document	Total citations	TC per year
Rubin RH, Moellering Jr RC. Clinical, microbiologic and therapeutic aspects of purulent pericarditis. The American Journal of Medicine 1975; 59: 68-78.	216	4.70
Wang ZJ, Reddy GP, Gotway MB, Yeh BM, Hetts SW, Higgins CB. CT and MR imaging of pericardial disease. Radiographics 2003; 23 (suppl_1): S167-80.	214	11.89
Taguchi R, Takasu J, Itani Y, Yamamoto R, Yokoyama K, Watanabe S, Masuda Y. Pericardial fat accumulation in men as a risk factor for coronary artery disease. Atherosclerosis 2001; 157: 203-9.	214	10.70
Talreja DR, Edwards WD, Danielson GK, Schaff HV, Tajik AJ, Tazelaar HD, Breen JF, Oh JK. Constrictive pericarditis in 26 patients with histologically normal pericardial thickness. Circulation 2003; 108: 1852-7.	212	11.78
Imazio M, Bobbio M, Cecchi E, Demarie D, Pomari F, Moratti M, Ghisio A, Belli R, Trinchero R. Colchicine as first-choice therapy for recurrent pericarditis: results of the CORE (COlchicine for REcurrent pericarditis) trial. Archives of Internal Medicine 2005; 165: 1987-91.	209	13.06
Klein AL, Abbara S, Agler DA, Appleton CP, Asher CR, Hoit B, Hung J, Garcia MJ, Kronzon I, Oh JK, Rodriguez ER. American Society of Echocardiography clinical recommendations for multimodality cardiovascular imaging of patients with pericardial disease: endorsed by the Society for Cardiovascular Magnetic Resonance and Society of Cardiovascular Computed Tomography. Journal of the American Society of Echocardiography 2013; 26: 965-1012.	207	25.88
Guberman BA, Fowler NO, Engel PJ, Gueron M, Allen JM. Cardiac tamponade in medical patients. Circulation 1981; 64: 633-40.	207	5.17
Feigenbaum H, Waldhausen JA, Hyde LP. Ultrasound diagnosis of pericardial effusion. JAMA 1965; 191: 711-4.	204	3.64
Wong CX, Abed HS, Molaee P, Nelson AJ, Brooks AG, Sharma G, Leong DP, Lau DH, Middeldorp ME, Roberts-Thomson KC, Wittert GA. Pericardial fat is associated with atrial fibrillation severity and ablation outcome. Journal of the American College of Cardiology 2011; 57: 1745-51.	203	20.30
Oh JK, Hatle LK, Seward JB, Danielson GK, Schaff HV, Reeder GS, Tajik AJ. Diagnostic role of Doppler echocardiography in constrictive pericarditis. Journal of the American College of Cardiology 1994; 23: 154-5.	203	7.52
Appleton CP, Hatle LK, Popp RL. Relation of transmitral flow velocity patterns to left ventricular diastolic function: new insights from a combined hemodynamic and Doppler echocardiographic study. Journal of the American College of Cardiology 1988; 12: 426-40.	201	6.09
Thanassoulis G, Massaro JM, O'Donnell CJ, Hoffmann U, Levy D, Ellinor PT, Wang TJ, Schnabel RB, Vasan RS, Fox CS, Benjamin EJ. Pericardial fat is associated with prevalent atrial fibrillation: the Framingham Heart Study. Circulation: Arrhythmia and Electrophysiology 2010; 3: 345-50.	200	18.18
Chiles C, Woodard PK, Gutierrez FR, Link KM. Metastatic involvement of the heart and pericardium: CT and MR imaging. Radiographics 2001; 21: 439-49.	199	9.95
Armstrong WF, Schilt BF, Helper DJ, Dillon JC, Feigenbaum H. Diastolic collapse of the right ventricle with cardiac tamponade: an echocardiographic study. Circulation 1982; 65: 1491-6.	197	5.05
Wood P. Chronic constrictive pericarditis. The American Journal of Cardiology 1961; 7: 48-61.	195	3.25
Al Chekakie MO, Welles CC, Metoyer R, Ibrahim A, Shapira AR, Cytron J, Santucci P, Wilber DJ, Akar JG. Pericardial fat is independently associated with human atrial fibrillation. Journal of the American College of Cardiology 2010; 56: 784-8.	191	17.36
Reddy PS, Curtiss EI, O'Toole JD, Shaver JA. Cardiac tamponade: hemodynamic observations in man. Circulation 1978; 58: 265-72.	190	4.42
Klacsmann PG, Bulkley BH, Hutchins GM. The changed spectrum of purulent pericarditis: an 86 year autopsy experience in 200 patients. The American Journal of Medicine 1977; 63:666-73.	190	4.32
Mayosi BM, Burgess LJ, Doubell AF. Tuberculous pericarditis. Circulation 2005; 112: 3608-16.	187	11.69
Weitzman LB, Tinker WP, Kronzon I, Cohen ML, Glassman E, Spencer FC. The incidence and natural history of pericardial effusion after cardiac surgery--an echocardiographic study. Circulation 1984; 69: 506-11.	184	4.97
Hancock EW. Subacute effusive-constrictive pericarditis. Circulation 1971; 43: 183-92.	184	3.68

Table I. Cont.

Document	Total citations	TC per year
Tyberg JV, Taichman GC, Smith ER, Douglas NW, Smiseth OA, Keon WJ. The relationship between pericardial pressure and right atrial pressure: an intraoperative study. Circulation 1986; 73: 428-32.	181	5.17
Dressler WW, Balieiro MC, de Araújo LF, Silva Jr WA, dos Santos JE. Culture as a mediator of gene-environment interaction: cultural consonance, childhood adversity, a 2A serotonin receptor polymorphism, and depression in urban Brazil. Social Science & Medicine 2016; 161: 109-17.	179	2.75
Adler Y, Finkelstein Y, Guindo J, Rodriguez de la Serna A, Shoenfeld Y, Bayes-Genis A, Sagie A, Bayes de Luna A, Spodick DH. Colchicine treatment for recurrent pericarditis: a decade of experience. Circulation 1998; 97: 2183-5.	178	7.74
Masui T, Finck S, Higgins CB. Constrictive pericarditis and restrictive cardiomyopathy: evaluation with MR imaging. Radiology 1992; 182: 369-73.	178	6.14
Gillam LD, Guyer DE, Gibson TC, King ME, Marshall JE, Weyman AE. Hydrodynamic compression of the right atrium: a new echocardiographic sign of cardiac tamponade. Circulation 1983; 68: 294-301.	177	4.66
Little WC, Freeman GL. Pericardial disease. Circulation 2006; 113: 1622-32.	176	11.73
Lange RA, Hillis LD. Acute pericarditis. New England Journal of Medicine 2004; 351: 2195-202.	176	10.35
Thurber DL, Edwards JE, Achor RW. Secondary malignant tumors of the pericardium. Circulation 1962; 26: 228-41.	174	2.95
Imazio M, Brucato A, Adler Y. A randomized trial of colchicine for acute pericarditis. The New England Journal of Medicine 2014; 370: 781.	168	21.00
Singh S, Wann LS, Schuchard GH, Klopfenstein HS, Leimgruber PP, Keelan Jr MH, Brooks HL. Right ventricular and right atrial collapse in patients with cardiac tamponade--a combined echocardiographic and hemodynamic study. Circulation 1984; 70: 966-71.	167	4.51
Scott RW, Garvin CF. Tumors of the heart and pericardium. American Heart Journal 1939; 17: 431-6.	164	2.00
Sagristà-Sauleda J, Mercé J, Permanyer-Miralda G, Soler-Soler J. Clinical clues to the causes of large pericardial effusions. The American Journal of Medicine 2000; 109: 95-101.	163	7.76
Zayas R, Anguita M, Torres F, Gime D, Bergillos F, Gallardo A, Valle F. Incidence of specific etiology and role of methods for specific etiologic diagnosis of primary acute pericarditis. American Journal of Cardiology 1995; 75: 378-82.	163	6.27
Imazio M, Spodick DH, Brucato A, Trinchero R, Adler Y. Controversial issues in the management of pericardial diseases. Circulation 2010; 121: 916-28.	163	14.82
Holt JP, Rhode EA, Kines H, Ruth H. Pericardial and ventricular pressure. Circulation Research 1960; 8: 1171-81.	162	2.66
Imazio M, Cecchi E, Demichelis B, Ierna S, Demarie D, Ghisio A, Pomari F, Coda L, Belli R, Trinchero R. Indicators of poor prognosis of acute pericarditis. Circulation 2007; 115: 2739-44.	161	11.50
Feigenbaum H. Echocardiographic diagnosis of pericardial effusion. The American Journal of Cardiology 1970; 26: 475-9.	159	3.12
Vaitkus PT, Herrmann HC, LeWinter MM. Treatment of malignant pericardial effusion. JAMA 1994; 272: 59-64	156	5.78
Imazio M, Brucato A, Cemin R, Ferrua S, Belli R, Maestroni S, Trinchero R, Spodick DH, Adler Y. Colchicine for recurrent pericarditis (CORP) a randomized trial. Annals of Internal Medicine 2011; 155: 409-14.	154	15.40
Krikorian JG, Hancock EW. Pericardiocentesis. The American Journal of Medicine 1978; 65: 808-14.	152	3.53
Boyle JD, Pearce ML, Guze LB. Purulent pericarditis: review of literature and report of eleven cases. Medicine 1961; 40: 119-44.	151	2.52
Cheng VY, Dey D, Tamarappoo B, Nakazato R, Gransar H, Miranda-Peats R, Ramesh A, Wong ND, Shaw LJ, Slomka PJ, Berman DS. Pericardial fat burden on ECG-gated noncontrast CT in asymptomatic patients who subsequently experience adverse cardiovascular events. JACC: Cardiovascular Imaging 2010; 3: 352-60.	149	13.55
Fulda G, Brathwaite CE, Rodriguez A, Turney SZ, Dunham CM, Cowley RA. Blunt traumatic rupture of the heart and pericardium: a ten-year experience (1979-1989). The Journal of Trauma 1991; 31: 167-72.	148	4.93

Table I. Cont.

Document	Total citations	TC per year
Cameron J, Oesterle SN, Baldwin JC, Hancock EW. The etiologic spectrum of constrictive pericarditis. American Heart Journal 1987; 113: 354-60.	148	4.35
Moncada R, Baker M, Salinas M, Demos TC, Churchill R, Love L, Reynes C, Hale D, Cardoso M, Pifarre R, Gunnar RM. Diagnostic role of computed tomography in pericardial heart disease: congenital defects, thickening, neoplasms, and effusions. American Heart Journal 1982; 103: 263-82.	148	3.79
Meaney E, Shabetai R, Bhargava V, Shearer M, Weidner C, Mangiardi LM, Smalling R, Peterson K. Cardiac amyloidosis, constrictive pericarditis and restrictive cardiomyopathy. The American Journal of Cardiology 1976; 38: 547-56.	147	3.27
Fox CS, Gona P, Hoffmann U, Porter SA, Salton CJ, Massaro JM, Levy D, Larson MG, D'Agostino RB, O'Donnell CJ, Manning WJ. Pericardial fat, intra-thoracic fat, and measures of left ventricular structure and function: the Framingham Heart Study. Circulation 2009; 119: 1586.	145	12.08
Deloach JF, Hayes JW. Secondary tumors of the pericardium and heart: review of the subject and a report of 137 cases. AMA Arch Intern Med 1953; 91: 224.	144	2.12
Sagristà-Sauleda J, Barrabés JA, Permanyer-Miralda G, Soler-Soler J. Purulent pericarditis: review of a 20-year experience in a general hospital. Journal of the American College of Cardiology 1993; 22: 1661-5.	142	5.07
Blalock A. A consideration of the nonoperative treatment of cardiac tamponade resulting from wounds of the heart. Surgery (St. Louis) 1943; 14: 157.	141	1.81
Holt JP. The normal pericardium. The American Journal of Cardiology 1970; 26: 455-65.	140	2.75
Fowler NO. Tuberculous pericarditis. JAMA 1991; 266: 99-103.	139	4.63
D'Cruz IA, Cohen HC, Prabhu R, Glick GE. Diagnosis of cardiac tamponade by echocardiography: changes in mitral valve motion and ventricular dimensions, with special reference to paradoxical pulse. Circulation 1975; 52: 460-5.	137	2.98
Callahan JA, Seward JB, Tajik AJ. Cardiac tamponade: pericardiocentesis directed by two-dimensional echocardiography. Mayo Clinic Proceedings 1985; 60: 344-7.	135	3.75
Bush CA, Stang JM, Wooley CF, Kilman JW. Occult constrictive pericardial disease. Diagnosis by rapid volume expansion and correction by pericardiectomy. Circulation 1977; 56: 924-30.	135	3.07
Spodick DH. The normal and diseased pericardium: current concepts of pericardial physiology, diagnosis and treatment. Journal of the American College of Cardiology 1983; 1: 240-51.	134	3.53
Imazio M, Demichelis B, Parrini I, Giuggia M, Cecchi E, Gaschino G, Demarie D, Ghisio A, Trinchero R. Day-hospital treatment of acute pericarditis: a management program for outpatient therapy. Journal of the American College of Cardiology 2004; 43: 1042-6.	133	7.82
Isaacs JP, Berglund E, Sarnoff SJ. Ventricular function: III. The pathologic physiology of acute cardiac tamponade studied by means of ventricular function curves. American Heart Journal 1954; 48: 66-76.	133	1.99
Corey GR, Campbell PT, Van Trigt P, Kenney RT, O'Connor CM, Sheikh KH, Kisslo JA, Wall TC. Etiology of large pericardial effusions. The American Journal of Medicine 1993; 95: 209-13.	132	4.71
Feigenbaum H, Zaky A, Grabhorn LL. Cardiac motion in patients with pericardial effusion: a study using reflected ultrasound. Circulation 1966; 34: 611-9.	130	2.36
McCaughan BC, Schaff HV, Piehler JM, Danielson GK, Orszulak TA, Puga FJ, Pluth JR, Connolly DC, McGoon DC. Early and late results of pericardiectomy for constrictive pericarditis. The Journal of Thoracic and Cardiovascular Surgery 1985; 89: 340-50.	129	3.58
Sagristà-Sauleda J, Angel J, Sánchez A, Permanyer-Miralda G, Soler-Soler J. Effusive–constrictive pericarditis. New England Journal of Medicine 2004; 350: 469-75.	128	7.53
Basso C, Valente M, Poletti A, Casarotto D, Thiene G. Surgical pathology of primary cardiac and pericardial tumors. European Journal of Cardiothoracic Surgery 1997; 12: 730-8.	126	5.25
Piehler JM, Pluth JR, Schaff HV, Danielson GK, Orszulak TA, Puga FJ. Surgical management of effusive pericardial disease: influence of extent of pericardial resection on clinical course. The Journal of Thoracic and Cardiovascular Surgery 1985; 90: 506-16.	124	3.44
Sechtem U, Tscholakoff D, Higgins CB. MRI of the abnormal pericardium. American Journal of Roentgenology 1986; 147: 245-52.	123	3.51

Table I. Cont.

Document	Total citations	TC per year
Rooney JJ, Crocco JA, Lyons HA. Tuberculous pericarditis. Annals of Internal Medicine 1970; 72: 73-8.	123	2.41
Heidenreich PA, Eisenberg MJ, Kee LL, Somelofski CA, Hollander H, Schiller NB, Cheitlin MD. Pericardial effusion in AIDS: incidence and survival. Circulation 1995; 92: 3229-34.	121	4.65
Imazio M, Trinchero R, Brucato A, Rovere ME, Gandino A, Cemin R, Ferrua S, Maestroni S, Zingarelli E, Barosi A, Simon C. COlchicine for the Prevention of the Post-pericardiotomy Syndrome (COPPS): a multicentre, randomized, double-blind, placebo-controlled trial. European Heart Journal 2010; 31: 2749-54.	120	10.91
Imazio M, Belli R, Brucato A, Cemin R, Ferrua S, Beqaraj F, Demarie D, Ferro S, Forno D, Maestroni S, Cumetti D. Efficacy and safety of colchicine for treatment of multiple recurrences of pericarditis (CORP-2): a multicentre, double-blind, placebo-controlled, randomised trial. The Lancet 2014; 383: 2232-7.	116	16.57
Cummings RG, Wesly RL, Adams DH, Lowe JE. Pneumopericardium resulting in cardiac tamponade. The Annals of Thoracic Surgery 1984; 37: 511-8.	115	3.11
Feigin DS, Fenoglio JJ, McAllister HA, Madewell JE. Pericardial cysts: a radiologic-pathologic correlation and review. Radiology 1977; 125: 15-20.	115	2.61
Mayosi BM. Contemporary trends in the epidemiology and management of cardiomyopathy and pericarditis in sub-Saharan Africa. Heart 2007; 93: 1176-83.	114	8.14
Rajagopalan N, Garcia MJ, Rodriguez L, Murray RD, Apperson-Hansen C, Stugaard M, Thomas JD, Klein AL. Comparison of new Doppler echocardiographic methods to differentiate constrictive pericardial heart disease and restrictive cardiomyopathy. The American Journal of Cardiology 2001; 87: 86-94.	114	5.70
Comty CM, Cohen SL, Shapiro FL. Pericarditis in chronic uremia and its sequels. Annals of Internal Medicine 1971; 75: 173-83.	114	2.28
Stark DD, Higgins CB, Lanzer P, Lipton MJ, Schiller N, Crooks LE, Botvinick EB, Kaufman L. Magnetic resonance imaging of the pericardium: normal and pathologic findings. Radiology 1984; 150: 469-74.	112	3.03
Khandaker MH, Espinosa RE, Nishimura RA, Sinak LJ, Hayes SN, Melduni RM, Oh JK. Pericardial disease: diagnosis and management. Mayo Clinic Proceedings 2010; 85: 572-93.	111	10.09
Levy PY, Corey R, Berger P, Habib G, Bonnet JL, Levy S, Messana T, Djiane P, Frances Y, Botta C, DeMicco P. Etiologic diagnosis of 204 pericardial effusions. Medicine 2003; 82: 385-91.	111	6.17
Hinderliter AL, Willis PW, Long W, Clarke WR, Ralph D, Caldwell EJ, Williams W, Ettinger NA, Hill NS, Summer WR, de Boisblanc B. Frequency and prognostic significance of pericardial effusion in primary pulmonary hypertension. American Journal of Cardiology 1999; 84: 481-4.	111	5.05
Posner MR, Cohen GI, Skarin AT. Pericardial disease in patients with cancer: the differentiation of malignant from idiopathic and radiation-induced pericarditis. The American Journal of Medicine 1981; 71: 407-13.	111	2.77
Mayosi BM, Ntsekhe M, Bosch J, Pandie S, Jung H, Gumedze F, Pogue J, Thabane L, Smieja M, Francis V, Joldersma L. Prednisolone and Mycobacterium indicus pranii in tuberculous pericarditis. New England Journal of Medicine 2014; 371: 1121-30.	110	15.71
Ding J, Kritchevsky SB, Harris TB, Burke GL, Detrano RC, Szklo M, Carr JJ, Multi-Ethnic Study of Atherosclerosis. The association of pericardial fat with calcified coronary plaque. Obesity 2008; 16: 1914-9.	110	8.46

Institutes of Health. There was no association between funding and the gender of the first or corresponding author.

Journal

Circulation (*n* = 26), *American Journal of Cardiology* (*n* = 11), and *Journal of American College of Cardiology* (*n* = 9) had the highest impact and together published ~50% of these manuscripts (S3 ????? Supplementary Figure S1 D).

Co-occurrence network of Keywords Plus

When two Keywords Plus appear together in a document, there are said to co-occur. The word is given in the rectangle; the size and the color of the rectangle depict the frequency and network of occurrence, respectively. Out of the four, one network (red) had the unique words "epicardial adipose tissue", "obesity" and "inflammation", suggesting an increase in research interest in this field.

Table II. Most relevant authors in the top 100 manuscripts

Author	Manuscripts	First author	Other	Corresponding author	Affiliation
Imazio M	10	9	1	9	Maria Vittoria Hospital, Department of Cardiology, Via Luigi Cibrario 72, Turin, Italy
Trinchero R	9	0	9	0	Maria Vittoria Hospital, Department of Cardiology, Via Luigi Cibrario 72, Turin, Italy
Adler Y	8	2	6	2	Sheba Medical Center, Tel Hashomer Hospital, City of Ramat-Gan, Tel Aviv, Israel
Spodick DH	8	2	6	2	Division of Cardiovascular Medicine, Department of Medicine, Saint Vincent Hospital–Worcester Medical Center, Worcester, Massachusetts, USA
Belli R	6	0	6	0	Maria Vittoria Hospital, Department of Cardiology, Via Luigi Cibrario 72, Turin, Italy
Brucato A	6	0	6	0	Azienda Ospedaliera Papa Giovanni XXIII, Bergamo, Italy
Demarie D	6	0	6	0	Maria Vittoria Hospital, Department of Cardiology, Via Luigi Cibrario 72, Turin, Italy
Schaff HV	6	0	6	0	Division of Cardiovascular Disease & Internal Medicine, Mayo Clinic & Mayo Foundation, Rochester, Minnesota, USA
Danielson GK	5	0	5	0	Division of Cardiovascular Disease & Internal Medicine, Mayo Clinic & Mayo Foundation, Rochester, Minnesota, USA
Klein AL	5	1	1	4	Cleveland Clinic Foundation, Department of Cardiology, Section of Cardiovasc Imaging, Cleveland, Ohio, USA

Content of the manuscript

Among the top 10 manuscripts, both guidelines provided a comprehensive review of etiology, classification, diagnosis, and management of pericardial diseases. Both guidelines were published by the European Society of Cardiology. Among the six original manuscripts, two studies evaluated the diagnostic accuracy of echocardiography to differentiate restrictive cardiomyopathy vs. constrictive pericarditis. Another two studies assessed the adverse prognostic role of pericardial fat on cardiovascular outcomes in primary prevention. There were 29 and 31 studies on clinical features, diagnosis, or management of pericardial effusion or tamponade and pericarditis, respectively (Supplementary Figure S3). There were eight and six manuscripts on pericardial fat and neoplasms, respectively.

Local citations

These manuscripts had 3156 local citations. The top 10% most locally cited publications had a peak in 2004 (cited 127 times), 1985 (cited 111 times), and 1990 (cited 103 times). These landmark papers may have impacted the field more than the other publications.

Discussion

In our analysis of the top 100 cited manuscripts on pericardial diseases, we found that most of the top-cited manuscripts were published in the period 2000–2009. This parallels the evolution of research in other fields of cardiology and is associated with advances in medical imaging and diagnostic techniques [5, 12]. Landmark manuscripts, such as by Dressler *et al*., were progressively cited less over time, suggesting a trend that certain facts and findings may become so fundamental in clinical practice that researchers no longer feel the need to cite the source article [13]. This phenomenon is called obliteration by incorporation, and it often contributes to recent time peaks in the bibliometric analysis [14].

Among the top 10 cited manuscripts, there were 2 guidelines on the management of pericardial diseases. The highest research output was from the United States and Europe, and in fact, both guidelines were published by the European Society of Cardiology. This suggests an unmet need for guidelines by professional cardiology institutions such as the American College of Cardiology and the American Heart Association, unlike their European counterparts. In recent years, cardiovascular con-

ditions such as valvular heart disease and heart failure have received more attention from professional cardiology societies with updated guidelines every few years [15, 16]. This is because of the high burden, rapid evolution in therapeutics, and high-quality data from randomized control trials in these fields. Currently, there is limited information on the morbidity and mortality associated with pericardial diseases. Initiation of or including data on pericardial diseases in ongoing registries such as the Atherosclerosis Risk in Communities study will help understand the actual burden and knowledge gaps for future research.

Pericardial diseases, such as pericarditis and effusion, were the most common themes explored in these manuscripts. For conservative management of pericarditis, a few therapeutic options such as colchicine or immunosuppression are available [17–19]. In our study, we found six randomized trials and all of them studied colchicine as a treatment modality for pericardial diseases. This indicates a possible unmet need for data exploring other treatment options. However, it is worth mentioning upcoming clinical trials on rilonacept, an IL-1 blocker, which is being investigated as a new therapeutic modality and offers new hope for the future.

Most manuscripts were published in one of the three major cardiology journals in the United States: *Circulation*, the *Journal of the American College of Cardiology*, and the *American Journal of Cardiology*. These findings demonstrate the application of Bradford's law, a bibliometric concept that indicates that researchers obtain a majority of their citations from a few leading journals, and whenever they deviate from these selected journals, the frequency of citations and impact decrease [20].

We found that there was an underrepresentation of women as first or corresponding authors, with a significant association between the gender of the first and the corresponding author, indicating that having women as first authors was less likely if the corresponding author was male. This imbalance pattern in scholarly output is similar to the trend seen in other fields in cardiology [21]. There were ten authors with ≥ 5 citations in the top 100 list, which is significantly higher than those seen in other bibliometrics. This may suggest that a few authors are publishing the bulk of the literature on pericardial diseases. We also found that an overwhelming proportion (n = 50) of the top-cited work was published by two countries – the United States and Italy – but only a few manuscripts had authors from ≥ 1 country. A better international collaboration, such as in heart failure, will help advance knowledge to generate high-quality data for diagnosis and management of pericardial diseases.

Our review of available data suggested that only 20% of manuscripts on pericardial diseases were funded. This is in sharp contrast to other fields of research in cardiology such as heart failure, where a similar study suggested that 86% of top-cited manuscripts were funded [22]. Most manuscripts on pericardial diseases were funded by government institutions such as the national institution of health. Lack of data on morbidity and mortality and limited options for management may be limiting industry sponsorship and progress in research in pericardial diseases. It would be interesting to see if this trend changes in the upcoming years with pharmaceutical companies funding trials such as those for IL-1 blockers as potential therapeutic targets.

In our analysis, we found a growing interest in the study of pericardial fat. Pericardial fat has been found to have an association with the burden of coronary artery disease and is hypothesized to drive local inflammation [23]. Improvement in medical imaging has advanced our understanding of how local fat deposits might be associated with diverse cardiac pathologies such as atherosclerosis and atrial fibrillation [23, 24]. With a shift in focus from infectious to metabolic diseases, research on the role of pericardial fat in the pathophysiology of cardiovascular diseases is likely to increase.

To the best of our knowledge, this is the first study to comprehensively review the current status of research in pericardial diseases. There are limitations to our analysis. The Web of Science database is updated weekly but the total citations may differ from other databases such as Google Scholar or PubMed [25]. Scopus has a wider range of sources and may yield more manuscripts with the same search words, but does not go as far back as Web of Science. The selection of top-cited manuscripts may exclude recently published landmark research. For example, a document published in 2020 with 10 citations is likely to be more relevant than a document published in 1970 with 200 citations (averaging 4 citations per year). The search strategy used may have missed other sources of pericardial research such as book chapters and online documents that were not cited in the literature.

In conclusion, in this bibliometric analysis of the top 100 cited manuscripts in pericardial diseases, we provide an insight on the characteristics and quality of the highly cited literature in the field of pericardial diseases. This can be used to guide further research in the field of pericardial diseases.

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Conflict of interest

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