A Scientific Analysis of the 100 Citation Classics of Valvular Heart Disease

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Bibliometric analyses can help researchers and research funding agencies determine which areas of medicine need appropriate research attention. Citation classics of several specialties and subspecialties have been published; however, a literature search did not turn up any in the field of valvular heart disease (VHD). The main objective of this analysis was to overcome this paucity by identifying the top 100 cited articles in VHD and to assess their characteristics. We chose Scopus as our database, from where relevant articles were extracted after a thorough search by 2 independent researchers. A list of the top 100 cited articles was prepared, after which a detailed analysis of the list was conducted. The top-cited articles were published in the 63-year era starting from 1951, with the most articles published in the 10-year interval of 2001 to 2010. The citations of the articles ranged from 438 to 2,717 with a median of 609.5. Manuscripts from our top-cited list originated from 25 different countries. Most of the articles in the top 100 list were published in high-impact journals, with about a third of the articles published in *Circulation* (n = 27). Our study also reveals that the current focus of researchers in the field is on transcatheter aortic valve replacement, and therefore, funding in this area is likely to result in impactful studies. In conclusion, our study highlights the characteristics of high-impact articles in the field of VHD, and this information may be useful for investigators planning to conduct studies in this area of medicine in the future. **(Am J Cardiol 2017;120:1440–1449)**

For several years, heart failure, arrhythmia, and myocardial infarction have held the center stage of cardiac diseases, whereas valvular heart diseases (VHDs) have been given relatively less attention. However, a strong association between age and VHD, combined with the rapid aging of the global population, has led to VHD being described as the "next cardiac epidemic."[1] The pressing need to address the increasing rates of VHD is the prime reason why research in this area is gaining importance. Moreover, the treatment options for VHD have grown over time, and the advent of modern techniques such as percutaneous valve repair or replacement has allowed treatment of previously inoperable cases. Trials such as "The Safety and Effectiveness of the SAPIEN 3 Transcatheter Heart Valve in Low Risk Patients With Aortic Stenosis" (PARTNER 3), which is currently in progress, are likely to expand the horizons for the treatment of VHD and further stimulate research interest in the area. Amidst a vast array of published literature, it is arduous to determine the true impact of a single research article within a field of study. Bibliometrics helps us separate landmark articles from the massive number of publications. This technique evaluates the trend and frequency of citations in the literature.[2] In an era that emphasizes cost productivity, citation analysis can be an important criterion to prioritize research funding toward areas where further research is required. Citation analysis does this by identifying which areas of medicine have received the requisite amount of academic attention and which areas have not. Citation classics in several specialties and subspecialties have been published.[3–8] However, a meticulous literature search revealed that there is no article listing the citation classics of "VHD." The purpose of the present study was to bridge this gap and to prepare a list of the landmark articles on VHD, and to identify important research trends. Furthermore, our study aimed to provide practicing cardiologists with a resource they could use to stay in touch with essential research in their field, which is crucial in today's world of evidence-based medicine.

Methods

The 100 most cited articles related to VHD were extracted from all available journals through an online database (Scopus Library database, www.scopus.com). It has been shown that Scopus, compared with other alternatives, has a more comprehensive coverage of articles.[9] In February 2017, 2 reviewers (MSU and TJS) independently searched Scopus. All types of articles were included. No time restriction was set. Articles on the epidemiology, diagnosis, treatment, and prognosis of VHD as their main focus were part of our inclusion criteria. For the purpose of the present study, infective endocarditis was considered to be a VHD, as it almost always

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involves valves.[10] Articles dealing with infection of cardiac implantable devices (sometimes classified as endocarditis) were excluded.

Keywords for the search were obtained from the International Classification of Diseases, Tenth Revision (ICD-10), from the following sections—(I05-I08), (I34-I38), and (Q22-Q23). This was done to ensure that no VHD was inadvertently excluded from our search criteria. The keywords included "Valve disorder," "Valvular disorder," "Rheumatic valve," "Valve disease," "Valvular disease," "Bicuspid valve," "Mitral valve," "Tricuspid valve," "Aortic valve," "Pulmonary valve," "Mitral stenosis," "Mitral insufficiency," "Mitral failure," "Mitral disorder," "Aortic stenosis," "Aortic insufficiency," "Aortic incompetence," "Aortic regurgitation," "Tricuspid stenosis," "Tricuspid insufficiency," "Multiple valve disease," "Mitral obstruction," "Mitral valve prolapse," "Endocarditis," "Valvulitis," "Valve atresia," "Pulmonary valve atresia," "Tricuspid atresia," "Mitral regurgitation," "rheumatic heart diseases," "tricuspid regurgitation," "pulmonic valve," "prosthetic heart valve," "Ebstein anomaly," "Hypoplastic right heart syndrome," "Aortic atresia," "Mitral atresia," "Hypoplastic left heart syndrome," "Bicuspid aortic valve," "Atrioventricular valve," and "Valvulopathy." The previously mentioned words were searched for in the article, abstract, and keywords.

Both reviewers searched Scopus over the same week and were kept oblivious to each other's findings. Articles were selected only if they strictly matched the inclusion criteria. The abstract of each search result was read thoroughly to judge the relevance of the article. If the abstract was not accessible on Scopus, it was sought from other sources, such as PubMed and Web of Science. The selected articles were arranged using the "cited by" option. A final list of 100 top-cited articles arranged in descending order was isolated, and the lists from both reviewers were compared. A difference of 6% was found among the lists. The discrepancies were solved by discussion until a consensus was reached.

The final list was exported to Microsoft Excel 2016, and a thorough analysis was conducted. For each article, the citation count, the year of publication, the country of origin, the number of authors, and the journal were extracted. The institutions of authors and their H-indexes were obtained from Scopus. Citations per year were calculated for all articles. Tables and charts were created using Microsoft Excel 2016. IBM SPSS v.23 (IBM, Chicago, IL) was used to apply the Pearson product moment correlation co\efficient to evaluate the relation between the impact factor of a journal and the number of articles of that journal in the top 100 list. Furthermore, the Mann-Whitney *U* test was applied to see whether there was any significant difference in the citations of review and original articles. A p value of <0.05 was considered significant.

Results

Table 1 lists the 100 most cited articles in the field of VHD, of which a majority are original articles (n = 85) and the rest were review articles (n = 15). In our list of the top 100 VHD articles, citations ranged from 438 to 2,717, with a median of 609.5 citations per article (interquartile range = 501.25 to 813.25). The total citations of all 100 articles were 77,288, and 7.5% of these citations were self-citations. There was no significant difference between the citations of review and original articles (p = 0.191). Citations per year ranged from 9.80 to 452.83 (mean = 79.73, median = 54.18, interquartile range = 31.54 to 90.37). Figure 1 shows the total citations accumulated by the 100 articles each year. The graph increases rapidly from 1996 onward, peaking in the 2013 to 2014 period. The 100 most cited articles in the field of VHD were published in 1951 to 2014. Figure 2 shows the distribution of these articles by the decade of publication. Most of the articles (n = 46) were published in 2001 to 2010.

Figure 3 shows that the 100 articles originated from 25 countries. More than half of the articles (n = 53) originated from the United States. Other major contributors included France (n = 20), Germany (n = 15), the United Kingdom (n = 15), and Canada (n = 14). The institutions that were affiliated with the most articles in our list were Duke University School of Medicine and Mayo Clinic (n = 11). These institutions were followed by Cleveland Clinic Foundation (n = 9). A total of 770 different authors contributed to the 100 articles in our list. The number of authors per article ranged from 1 to 66, with a median of 10 authors per article. Of the 770 authors, 229 had more than 1 article in the list. Table 2 lists the most prolific authors in the field of VHD, along with their institution and H-index. Martin B. Leon tops the list with 13 articles, followed by Catherine M. Otto (n = 12) and John G. Webb (n = 11). The top 100 articles originated from 20 different journals. Table 3 lists the journals with 3 or more articles in the list. We found no significant correlation between the impact factor of a journal and the number of articles of that journal in the top 100 list (p = 0.113).

Table 4 lists the articles divided according to their main theme. Many (n = 40) of the articles focused on the treatment of VHD; with considerably lesser numbers focusing on diagnosis, prevalence, prognosis, prevention, and causes. Almost half of the articles (n = 43) did not study any specific valve, and aortic valve was the most common individual valve studied (n = 39).

Discussion

The articles distinguished in Table 1 can be appraised as the "research core" in the field of VHD. A citation analysis of these articles can provide insight on the research activity within this field. Although traditionally it has been considered that review articles are more likely to be cited than original articles,[11] we found no significant difference in the citations of review and original articles among the landmark articles of VHD (p = 0.191).

Figure 2 demonstrates that a vast majority of the studies (n = 80) from the top-cited articles were published from 1981 to 2010. After this era, the period after 2010 also continues to produce highly cited articles (n = 13). However, previous decades had fewer citations—this outlines that progress in the field of VHD is recent and that work continues in this area. Our results concur with the trend seen in the field of cardiology,[6,7,12] which shows that research in the field of VHD is developing in the same modern era as cardiology as a whole. Our pattern is contrary to other bibliometrics in well-established fields, where peaks were observed from 1965 to 1980, such as those of neurosurgery,[13] orthopedics,[5] and general surgery.[4] An increase in the prevalence of VHD worldwide

Table 1
Top 100 cited articles, their citations, and citations

Rank	Article
1	Leon MB, Smith CR, Mack M, Miller DC, Moses JW, Svensson LG, Tuzcu EM, Webb JG, Fontana GP, Makkar RR, Brown DL, Block PC, Guyton RA, Pichard AD, Bavaria JE, Herrmann HC, Douglas PS, Petersen JL, Akin JJ, Anderson WN, Wang D, Pocock S. T**ranscatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery.** *New Engl J Med* 2010;17:1597–1607. **(2717; 453; 1)**
2	Zoghbi WA, Enriquez-Sarano M, Foster E, Grayburn PA, Kraft CD, Levine RA, Nihoyannopoulos P, Otto CM, Quinones MA, Rakowski H, Stewart WJ, Waggoner A, Weissman NJ. **Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography.** *J Am Soc Echocardiogr* 2003;7:777–802. **(2341; 180; 7)**
3	Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG, Tuzcu EM, Webb JG, Fontana GP, Makkar RR, Williams M, Dewey T, Kapadia S, Babaliaros V, Thourani VH, Corso P, Pichard AD, Bavaria JE, Herrmann HC, Akin JJ, Anderson WN, Wang D, Pocock SJ. **Transcatheter versus surgical aortic-valve replacement in high-risk patients.** *New Engl J Med* 2011;23:2187–2198. **(2170; 434; 2)**
4	Durack DT, Lukes AS, Bright DK, Duke Endocarditis Service. **New criteria for diagnosis of infective endocarditis: Utilization of specific echocardiographic findings.** *Am J Med* 1994;2:200–209. **(1734; 79; 34)**
5	Vahanian A, Alfieri O, Andreotti F, Antunes MJ, Barón-Esquivias G, Baumgartner H, Borger MA, Carrel TP, De Bonis M, Evangelista A, Falk V, Iung B, Lancellotti P, Pierard L, Price S, Schäfers H-, Schuler G, Stepinska J, Swedberg K, Takkenberg J, Von Oppell UO, Windecker S, Zamorano JL, Zembala M, Bax JJ, Ceconi C, Dean V, Deaton C, Fagard R, Funck-Brentano C, Hasdai D, Hoes A, Kirchhof P, Knuuti J, Kolh P, McDonagh T, Moulin C, Popescu BA, Reiner Ž, Sechtem U, Sirnes PA, Tendera M, Torbicki A, Von Segesser L, Badano LP, Bunc M, Claeys MJ, Drinkovic N, Filippatos G, Habib G, Pieter Kappetein A, Kassab R, Lip GYH, Moat N, Nickenig G, Otto CM, Pepper J, Piazza N, Pieper PG, Rosenhek R, Shuka N, Schwammenthal E, Schwitter J, Mas PT, Trindade PT, Walther T. **Guidelines on the management of valvular heart disease (version 2012).** *Eur Heart J* 2012;19:2451–2496. **(1640; 410; 3)**
6	Cribier A, Eltchaninoff H, Bash A, Borenstein N, Tron C, Bauer F, Derumeaux G, Anselme F, Laborde F, Leon MB. **Percutaneous transcatheter implantation of an aortic valve prosthesis for calcific aortic stenosis: First human case description.** *Circulation*2002;24:3006–3008. **(1624; 116; 19)**
7	Vahanian A, Baumgartner H, Bax J, Butchart E, Dion R, Filippatos G, Flachskampf F, Hall R, Lung B, Kasprzak J, Nataf P, Tornos P, Torracca L, Wenink A. **Guidelines on the management of valvular heart disease: The task force on the management of valvular heart disease of the European Society of Cardiology.** *Eur Heart J* 2007;2:230–268. **(1613; 179; 8)**
8	Li JS, Sexton DJ, Mick N, Nettles R, Fowler VG, Ryan T, Bashore T, Corey GR. **Proposed modifications to the duke criteria for the diagnosis of infective endocarditis.** *Clin Infect Dis* 2000;4:633–638. **(1590; 99; 25)**
9	Iung B, Baron G, Butchart EG, Delahaye F, Gohlke-Bärwolf C, Levang OW, Tornos P, Vanoverschelde J-, Vermeer F, Boersma E, Ravaud P, Vahanian A. **A prospective survey of patients with valvular heart disease in Europe: The Euro Heart Survey on Valvular Heart Disease.** *Eur Heart J* 2003;13:1231–1243. **(1534; 118; 18)**
10	Bonow RO, Carabello BA, Chatterjee K, De Leon Jr. AC, Faxon DP, Freed MD, Gaasch WH, Lytle BW, Nishimura RA, O'Gara PT, O'Rourke RA, Otto CM, Shah PM, Shanewise JS. **ACC/AHA 2006 guidelines for the management of patients with valvular heart disease: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (writing committee to revise the 1998 guidelines for the management of patients with valvular heart disease)—developed in collaboration with the society of cardiovascular anesthesiologists.** *Circulation* 2006;5:e84-e231. **(1475; 148; 11)**
11	Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. **Burden of valvular heart diseases: A population-based study.** *Lancet*2006;9540:1005–1011. **(1274; 127; 15)**
12	Fontan F, Baudet E. **Surgical repair of tricuspid atresia.** *Thorax* 1971;3:240–248. **(1217; 27; 83)**
13	Carpentier A. **Cardiac valve surgery: The 'French correction'.** *J Thorac Cardiovasc Surg* 1983;3:323–337. **(1214; 37; 68)**
14	Habib G, Hoen B, Tornos P, Thuny F, Prendergast B, Vilacosta I, Moreillon P, De Jesus Antunes M, Thilen U, Lekakis J, Lengyel M, Müller L, Naber CK, Nihoyannopoulos P, Moritz A, Zamorano JL, Vahanian A, Auricchio A, Bax J, Ceconi C, Dean V, Filippatos G, Funck-Brentano C, Hobbs R, Kearney P, McDonagh T, McGregor K, Popescu BA, Reiner Z, Sechtem U, Sirnes PA, Tendera M, Vardas P, Widimsky P, Aguilar R, Bongiorni MG, Borger M, Butchart E, Danchin N, Delahaye F, Erbel R, Franzen D, Gould K, Hall R, Hassager C, Kjeldsen K, McManus R, Miró JM, Mokracek A, Rosenhek R, San Román Calvar JA, Seferovic P, Selton-Suty C, Uva MS, Trinchero R, Van Camp G. **Guidelines on the prevention, diagnosis, and treatment of infective endocarditis (new version 2009).** *Eur Heart J*2009;19:2369–2413. **(1135; 162; 9)**
15	Wilson W, Taubert KA, Gewitz M, Lockhart PB, Baddour LM, Levison M, Bolger A, Cabell CH, Takahashi M, Baltimore RS, Newburger JW, Strom BL, Tani LY, Gerber M, Bonow RO, Pallasch T, Shulman ST, Rowley AH, Burns JC, Ferrieri P, Gardner T, Goff D, Durack DT. **Prevention of infective endocarditis: Guidelines from the American Heart Association.** *Circulation* 2007;15:1736–1754. **(1118; 124; 16)**
16	Kodali SK, Williams MR, Smith CR, Svensson LG, Webb JG, Makkar RR, Fontana GP, Dewey TM, Thourani VH, Pichard AD, Fischbein M, Szeto WY, Lim S, Greason KL, Teirstein PS, Malaisrie SC, Douglas PS, Hahn RT, Whisenant B, Zajarias A, Wang D, Akin JJ, Anderson WN, Leon MB. **Two-year outcomes after transcatheter or surgical aortic-valve replacement.** *New Engl J Med* 2012;18:1686–1695. **(1102; 276; 6)**
17	Stewart BF, Siscovick D, Lind BK, Gardin JM, Gottdiener JS, Smith VE, Kitzman DW, Otto CM. **Clinical factors associated with calcific aortic valve disease.** *J Am Coll Cardiol* 1997;3:630–634. **(1095; 58; 46)**
18	Connolly HM, Crary JL, McGoon MD, Hensrud DD, Edwards BS, Edwards WD, Schaff HV. **Valvular heart disease associated with fenfluramine phentermine.** *New Engl J Med* 1997;9:581–588. **(1091; 57; 47)**
19	Yock PG, Popp RL. **Noninvasive estimation of right ventricular systolic pressure by Doppler ultrasound in patients with tricuspid regurgitation.** *Circulation* 1984;4:657–662. **(1071; 33; 71)**
20	Baddour LM, Wilson WR, Bayer AS, Fowler Jr. VG, Bolger AF, Levison ME, Ferrieri P, Gerber MA, Tani LY, Gewitz MH, Tong DC, Steckelberg JM, Baltimore RS, Shulman ST, Burns JC, Falace DA, Newburger JW, Pallasch TJ, Takahashi M, Taubert KA. **Infective endocarditis: Diagnosis, antimicrobial therapy, and management of complications: A statement for healthcare professionals from the committee on rheumatic fever, endocarditis, and kawasaki disease, council on cardiovascular disease in the young, and the councils on clinical cardiology, stroke, and cardiovascular surgery and anesthesia, American Heart Association: Endorsed by the.** *Circulation*2005;23:e394-434. **(1032; 94; 26)**

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Table 1
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Rank	Article
21	Bonow RO, Carabello BA, Chatterjee K, de Leon Jr. AC, Faxon DP, Freed MD, Gaasch WH, Lytle BW, Nishimura RA, O'Gara PT, O'Rourke RA, Otto CM, Shah PM, Shanewise JS, Nishimura RA, Carabello BA, Faxon DP, Freed MD, Lytle BW, O'Gara PT, O'Rourke RA, Shah PM. **2008 focused update incorporated into the ACC/AHA 2006 guidelines for the management of patients with valvular heart disease. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (writing committee to revise the 1998 guidelines for the management of patients with valvular heart disease).** *J Am Coll Cardiol* 2008;13:e1-e142. **(947; 118; 17)**
22	Gorlin R, Gorlin SG. **Hydraulic formula for calculation of the area of the stenotic mitral valve, other cardiac valves, and central circulatory shunts. I.** *Am Heart J* 1951;1:1–29. **(853; 13; 96)**
23	Mylonakis E, Calderwood SB. **Infective endocarditis in adults.** *New Engl J Med* 2001;18:1318–1330. **(832; 55; 49)**
24	Rossebø AB, Pedersen TR, Boman K, Brudi P, Chambers JB, Egstrup K, Gerdts E, Gohlke-Bärwolf C, Holme I, Kesäniemi YA, Malbecq W, Nienaber CA, Ray S, Skjærpe T, Wachtell K, Willenheimer R. **Intensive lipid lowering with simvastatin and ezetimibe in aortic stenosis.** *New Engl J Med* 2008;13:1343–1356. **(824; 103; 23)**
25	Grigioni F, Enriquez-Sarano M, Zehr KJ, Bailey KR, Tajik AJ. **Ischemic mitral regurgitation: Long-term outcome and prognostic implications with quantitative Doppler assessment.** *Circulation* 2001;13:1759–1764. **(814; 54; 50)**
26	Inoue K, Owaki T, Nakamura T, Kitamura F, Miyamoto N. **Clinical application of transvenous mitral commissurotomy by a new balloon catheter.** *J Thorac Cardiovasc Surg* 1984;3:394–402. **(813; 25;87)**
27	Webb JG, Pasupati S, Humphries K, Thompson C, Altwegg L, Moss R, Sinhal A, Carere RG, Munt B, Ricci D, Ye J, Cheung A, Lichtenstein SV. **Percutaneous transarterial aortic valve replacement in selected high-risk patients with aortic stenosis.** Circulation 2007;7:755–763. **(803;89; 28)**
28	**ACC/AHA guidelines for the management of patients with valvular heart disease. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Patients with Valvular Heart Disease).** *J Am Coll Cardiol* 1998;5:1486–1588. **(799; 44; 60)**
29	Dajani AS, Taubert KA, Wilson W, Bolger AF, Bayer A, Ferrieri P, Gewitz MH, Shulman ST, Nouri S, Newburger JW, Hutto C, Pallasch TJ, Gage TW, Levison ME, Peter G, Zuccaro Jr. G. **Prevention of bacterial endocarditis: Recommendations by the American Heart Association.** *J Am Med Assoc* 1997;22:1794–1801. **(793;42;63)**
30	Otto CM, Lind BK, Kitzman DW, Gersh BJ, Siscovick DS. **Association of aortic-valve sclerosis with cardiovascular mortality and morbidity in the elderly**. *New Engl J Med* 1999;3:142–147. **(791; 47; 58)**
31	Otto CM, Kuusisto J, Reichenbach DD, Gown AM, O'Brien KD. **Characterization of the early lesion of 'degenerative' valvular aortic stenosis: Histological and immunohistochemical studies.** *Circulation* 1994;2:844–853. **(767; 35; 69)**
32	Rosenhek R, Binder T, Porenta G, Lang I, Christ G, Schemper M, Maurer G, Baumgartner H. **Predictors of outcome in severe, asymptomatic aortic stenosis.** *New Engl J Med* 2000;9:611–617. **(750; 47; 57)**
33	Grube E, Schuler G, Buellesfeld L, Gerckens U, Linke A, Wenaweser P, Sauren B, Mohr F-, Walther T, Zickmann B, Iversen S, Felderhoff T, Cartier R, Bonan R. **Percutaneous aortic valve replacement for severe aortic stenosis in high-risk patients using the second- and current third-generation self-expanding CoreValve prosthesis. Device success and 30-day clinical outcome.** *J Am Coll Cardiol* 2007;1:69–76. **(748; 83; 32)**
34	Bonow RO, Carabello B, De Leon A.C. J, Edmunds L.H. J, Fedderly BJ, Freed MD, Gaasch WH, McKay CR, Nishimura RA, O'Gara PT, O'Rourke RA, Rahimtoola SH. **Guidelines for the management of patients with valvular heart disease: Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Patients with Valvular Heart Disease).** *Circulation* 1998;18:1949–1984. **(735; 41; 65)**
35	Wilkins GT, Weyman AE, Abascal VM, Block PC, Palacios IF. **Percutaneous balloon dilatation of the mitral valve: An analysis of echocardiographic variables related to outcome and the mechanism of dilatation.** *Heart* 1988;4:299–308. **(731; 26; 85)**
36	Lindroos M, Kupari M, Heikkilä J, Tilvis R. **Prevalence of aortic valve abnormalities in the elderly: An echocardiographic study of a random population sample.** *J Am Coll Cardiol* 1993;5:1220–1225. **(730; 32; 74)**
37	Cannegieter SC, Rosendaal FR, Wintzen AR, Van der Meer FJM, Vandenbroucke JP, Briet E. **Optimal oral anticoagulant therapy in patients with mechanical heart valves.** *New Engl J Med* 1995;1:11–17. **(724; 33; 73)**
38	Perry GJ, Helmcke F, Nanda NC, Byard C, Soto B. **Evaluation of aortic insufficiency by Doppler color flow mapping.** *J Am Coll Cardiol* 1987;4:952–959. **(724; 25; 88)**
39	Ross Jr. J, Braunwald E. **Aortic stenosis.** Circulation 1968;1 Suppl:61–67. **(684; 14; 95)**
40	Garg V, Muth AN, Ransom JF, Schluterman MK, Barnes R, King IN, Grossfeld PD, Srivastava D. **Mutations in NOTCH1 cause aortic valve disease.** *Nature* 2005;7056:270–274. **(682; 62; 43)**
41	Webb JG, Chandavimol M, Thompson CR, Ricci DR, Carere RG, Munt BI, Buller CE, Pasupati S, Lichtenstein S. **Percutaneous aortic valve implantation retrograde from the femoral artery.** *Circulation* 2006;6:842–850. **(680; 68; 36)**
42	Iung B, Cachier A, Baron G, Messika-Zeitoun D, Delahaye F, Tornos P, Gohlke-Bärwolf C, Boersma E, Ravaud P, Vahanian A. **Decision-making in elderly patients with severe aortic stenosis: Why are so many denied surgery?** *Eur Heart J* 2005;24:2714–2720. **(674; 61; 44)**
43	Tamburino C, Capodanno D, Ramondo A, Petronio AS, Ettori F, Santoro G, Klugmann S, Bedogni F, Maisano F, Marzocchi A, Poli A, Antoniucci D, Napodano M, De Carlo M, Fiorina C, Ussia GP. **Incidence and predictors of early and late mortality after transcatheter aortic valve implantation in 663 patients with severe aortic stenosis.** *Circulation* 2011;3:299–308. **(671; 134; 13)**
44	David TE, Feindel CM. **An aortic valve-sparing operation for patients with aortic incompetence and aneurysm of the ascending aorta.** *J Thorac Cardiovasc Surg* 1992;4:617–622. **(667; 28; 82)**
45	Cannegieter SC, Rosendaal FR, Briët E. **Thromboembolic and bleeding complications in patients with mechanical heart valve prostheses.** *Circulation* 1994;2:635–641. **(662; 30; 77)**

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Rank	Article
46	Rodés-Cabau J, Webb JG, Cheung A, Ye J, Dumont E, Feindel CM, Osten M, Natarajan MK, Velianou JL, Martucci G, DeVarennes B, Chisholm R, Peterson MD, Lichtenstein SV, Nietlispach F, Doyle D, DeLarochellière R, Teoh K, Chu V, Dancea A, Lachapelle K, Cheema A, Latter D, Horlick E. **Transcatheter aortic valve implantation for the treatment of severe symptomatic aortic stenosis in patients at very high or prohibitive surgical risk. acute and late outcomes of the multicenter Canadian experience.** *J Am Coll Cardiol* 2010;11:1080–1090. **(645; 108; 21)**
47	Feldman T, Foster E, Glower DG, Kar S, Rinaldi MJ, Fail PS, Smalling RW, Siegel R, Rose GA, Engeron E, Loghin C, Trento A, Skipper ER, Fudge T, Letsou GV, Massaro JM, Mauri L. **Percutaneous repair or surgery for mitral regurgitation.** *New Engl J Med* 2011;15:1395–1406. **(644; 129; 14)**
48	Gilard M, Eltchaninoff H, Iung B, Donzeau-Gouge P, Chevreul K, Fajadet J, Leprince P, Leguerrier A, Lievre M, Prat A, Teiger E, Lefevre T, Himbert D, Tchetche D, Carrié D, Albat B, Cribier A, Rioufol G, Sudre A, Blanchard D, Collet F, Dos Santos P, Meneveau N, Tirouvanziam A, Caussin C, Guyon P, Boschat J, Le Breton H, Collart F, Houel R, Delpine S, Souteyrand G, Favereau X, Ohlmann P, Doisy V, Grollier G, Gommeaux A, Claudel J-, Bourlon F, Bertrand B, Van Belle E, Laskar M. **Registry of transcatheter aortic-valve implantation in high-risk patients.** *New Engl J Med* 2012;18:1705–1715. **(630; 158; 10)**
49	Otto CM, Burwash IG, Legget ME, Munt BI, Fujioka M, Healy NL, Kraft CD, Miyake-Hull CY, Schwaegler RG. **Prospective study of asymptomatic valvular aortic stenosis: Clinical, echocardiographic, and exercise predictors of outcome.** *Circulation* 1997;9:2262–2270. **(630; 33; 72)**
50	Hoen B, Alla F, Selton-Suty C, Béguinot I, Bouvet A, Briançon S, Casalta J-, Danchin N, Delahaye F, Etienne J, Le Moing V, Leport C, Mainardi J-, Ruimy R, Vandenesch F. **Changing profile of infective endocarditis: Results of a 1-year survey in france.** *J Am Med Assoc* 2002;1:75–81. **(611; 44; 61)**
51	Mohler III ER, Gannon F, Reynolds C, Zimmerman R, Keane MG, Kaplan FS. **Bone formation and inflammation in cardiac valves.** *Circulation* 2001;11:1522–1528. **(608; 41; 66)**
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53	Thomas M, Schymik G, Walther T, Himbert D, Lefèvre T, Treede H, Eggebrecht H, Rubino P, Michev I, Lange R, Anderson WN, Wendler O. **Thirty-day results of the SAPIEN aortic bioprosthesis eEropean outcome (SOURCE) registry: A European registry of transcatheter aortic valve implantation using the Edwards SAPIEN valve.** *Circulation* 2010;1:62–69. **(598; 100; 24)**
54	Moreillon P, Que Y-. **Infective endocarditis.** *Lancet* 2004;9403:139–149. **(597; 50; 56)**
55	Fowler Jr. VG, Miro JM, Hoen B, Cabell CH, Abrutyn E, Rubinstein E, Corey GR, Spelman D, Bradley SF, Barsic B, Pappas PA, Anstrom KJ, Wray D, Fortes CQ, Anguera I, Athan E, Jones P, Van Der Meer JTM, Elliott TSJ, Levine DP, Bayer AS. **Staphylococcus aureus endocarditis: A consequence of medical progress.** *J Am Med Assoc* 2005;24:3012–3021. **(595; 54; 51)**
56	Cowell SJ, Newby DE, Prescott RJ, Bloomfield P, Reid J, Northridge DB, Boon NA. **A randomized trial of intensive lipid-lowering therapy in calcific aortic stenosis.** *New Engl J Med* 2005;352(23):2389–2397. **(588; 53; 52)**
57	Murdoch DR, Corey RG, Hoen B, Miró M, Fowler VG, Bayer AS, Karchmer AW, Olaison L, Pappas PA, Moreillon P, Chambers ST, Chu VH, Falcó V, Holland DJ, Jones P, Klein JL, Raymond NJ, Read KM, Tripodi MF, Utili R, Wang A, Woods CW, Cabell CH. **Clinical presentation, etiology, and outcome of infective endocarditis in the 21st century the international collaboration on endocarditis-prospective cohort study.** *Arch Intern Med* 2009;5:463–473. **(583; 83; 31)**
58	Adams DH, Popma JJ, Reardon MJ, Yakubov SJ, Coselli JS, Deeb GM, Gleason TG, Buchbinder M, Hermiller Jr. J, Kleiman NS, Chetcuti S, Heiser J, Merhi W, Zorn G, Tadros P, Robinson N, Petrossian G, Hughes GC, Harrison JK, Conte J, Maini B, Mumtaz M, Chenoweth S, Oh JK. **Transcatheter aortic-valve replacement with a self-expanding prosthesis.** *New Engl J Med* 2014;19:1790–1798. **(580; 290; 4)**
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60	Cribier A, Eltchaninoff H, Tron C, Bauer F, Agatiello C, Nercolini D, Tapiero S, Litzler P-, Bessou J-, Babaliaros V. **Treatment of calcific aortic stenosis with the percutaneous heart valve: Mid-term follow-up from the initial feasibility studies: The French experience.** *J Am Coll Cardiol* 2006;6:1214–1223. **(573; 57; 48)**
61	von Reyn CF, Levy BS, Arbeit RD, Friedland G, Crumpacker CS. Infective endocarditis: **An analysis based on strict case definitions.** *Ann Intern Med* 1981;4 I:505–518. **(573; 16; 93)**
62	WILLIAMS JC, BARRATT-BOYES BG, LOWE JB. **Supravalvular aortic stenosis.** *Circulation* 1961;24:1311–1318. **(554; 10; 99)**
63	Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin III JP, Guyton RA, O'Gara PT, Ruiz CE, Skubas NJ, Sorajja P, Sundt III TM, Thomas JD. **2014 AHA/ACC guideline for the management of patients with valvular heart disease: Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines.** *J Am Coll Cardiol* 2014;22:2438–2488. **(553; 277; 5)**
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65	Hammermeister K, Sethi GK, Henderson WG, Grover FL, Oprian C, Rahimtoola SH. **Outcomes 15 years after valve replacement with a mechanical versus a bioprosthetic valve: Final report of the veterans affairs randomized trial.** *J Am Coll Cardiol* 2000;4:1152–1158. **(537; 34; 70)**
66	Zanettini R, Antonini A, Gatto G, Gentile R, Tesei S, Pezzoli G. **Valvular heart disease and the use of dopamine agonists for Parkinson's disease.** *New Engl J Med* 2007;1:39–46. **(531; 59; 45)**
67	Grube E, Laborde JC, Gerckens U, Felderhoff T, Sauren B, Buellesfeld L, Mueller R, Menichelli M, Schmidt T, Zickmann B, Iversen S, Stone GW. **Percutaneous implantation of the CoreValve self-expanding valve prosthesis in high-risk patients with aortic valve disease: The Siegburg first-in-man study.** *Circulation* 2006;15:1616–1624. **(518; 52; 54)**

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Rank	Article
68	Moat NE, Ludman P, De Belder MA, Bridgewater B, Cunningham AD, Young CP, Thomas M, Kovac J, Spyt T, MacCarthy PA, Wendler O, Hildick-Smith D, Davies SW, Trivedi U, Blackman DJ, Levy RD, Brecker SJD, Baumbach A, Daniel T, Gray H, Mullen MJ. **Long-term outcomes after transcatheter aortic valve implantation in high-risk patients with severe aortic stenosis: The U.K. TAVI (united kingdom transcatheter aortic valve implantation) registry.** *J Am Coll Cardiol* 2011;20:2130–2138. **(516; 103; 22)**
69	Piazza N, Grube E, Gerckens U, den Heijer P, Linke A, Luha O, Ramondo A, Ussia G, Wenaweser P, Windecker S, Laborde JC, de Jaegere P, Serruys PW. **Procedural and 30-day outcomes following transcatheter aortic valve implantation using the third generation (18 fr) corevalve revalving system: Results from the multicentre, expanded evaluation registry 1-year following CE mark approval.** *EuroIntervention* 2008;2:242–249. **(512; 64; 39)**
70	Roberts WC. **The congenitally bicuspid aortic valve. A study of 85 autopsy cases.** *Am J Cardiol* 1970;1:72–83. **(511; 11; 98)**
71	Vahanian A, Alfieri O, Al-Attar N, Antunes M, Bax J, Cormier B, Cribier A, De Jaegere P, Fournial G, Kappetein AP, Kovac J, Ludgate S, Maisano F, Moat N, Mohr F, Nataf P, Piérard L, Pomar JL, Schofer J, Tornos P, Tuzcu M, Van Hout B, Von Segesser LK, Walther T. **Transcatheter valve implantation for patients with aortic stenosis: A position statement from the European Association of Cardio-thoracic Surgery (EACTS) and the European Society of Cardiology (ESC), in collaboration with the European Association of Percutaneous Cardiovascular Interventions (EAPCI).** *Eur Heart J* 2008;11:1463–1470. **(507; 63; 42)**
72	Bonhoeffer P, Boudjemline Y, Saliba Z, Merckx J, Aggoun Y, Bonnet D, Acar P, Le Bidois J, Sidi D, Kachaner J. **Percutaneous replacement of pulmonary valve in a right-ventricle to pulmonary-artery prosthetic conduit with valve dysfunction.** *Lancet* 2000;9239:1403–1405. **(506; 32; 75)**
73	Bayer AS, Bolger AF, Taubert KA, Wilson W, Steckelberg J, Karchmer AW, Levison M, Chambers HF, Dajani AS, Gewitz MH, Newburger JW, Gerber MA, Shulman ST, Pallasch TJ, Gage TW, Ferrieri P. **Diagnosis and management of infective endocarditis and its complications.** *Circulation* 1998;25:2936–2948. **(506; 28; 81)**
74	Enriquez-Sarano M, Schaff HV, Orszulak TA, Tajik AJ, Bailey KR, Frye RL. **Valve repair improves the outcome of surgery for mitral regurgitation: A multivariate analysis.** *Circulation*1995;4:1022–1028. **(505; 24; 90)**
75	Freed LA, Levy D, Levine RA, Larson MG, Evans JC, Fuller DL, Lehman B, Benjamin EJ. **Prevalence and clinical outcome of mitral-valve prolapse.** *New Engl J Med* 1999;1:1–7. **(502; 30; 78)**
76	Vongpatanasin W, Hillis LD, Lange RA. **Prosthetic heart valves.** *New Engl J Med* 1996;6:407–416. **(499; 25; 89)**
77	Horstkotte D, Follath F, Gutschik E, Lengyel M, Oto A, Pavie A, Soler-Soler J, Thiene G, Von Graevenitz A. **Guidelines on prevention, diagnosis and treatment of infective endocarditis executive summary: The task force on infective endocarditis of the European Society of Cardiology.** *Eur Heart J* 2004;3:267–276. **(494; 41; 64)**
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79	Chan WS, Anand S, Ginsberg JS. **Anticoagulation of pregnant women with mechanical heart valves: A systematic review of the literature.** *Arch Intern Med* 2000;2:191–196. **(487; 29; 80)**
80	O'Brien SM, Shahian DM, Filardo G, Ferraris VA, Haan CK, Rich JB, Normand S-T, DeLong ER, Shewan CM, Dokholyan RS, Peterson ED, Edwards FH, Anderson RP. **The society of thoracic surgeons 2008 cardiac surgery risk models: Part 2-isolated valve surgery.** *Ann Thorac Surg* 2009;1 SUPPL.:S23-42. **(487; 70; 35)**
81	Cribier A, Eltchaninoff H, Tron C, Bauer F, Agatiello C, Sebagh L, Bash A, Nusimovici D, Litzler PY, Bessou J-, Leon MB. **Early experience with percutaneous transcatheter implantation of heart valve prosthesis for the treatment of end-stage inoperable patients with calcific aortic stenosis.** *J Am Coll Cardiol* 2004;4:698–703. **(485; 40; 67)**
82	Ross DN. **Replacement of aortic and mitral valves with a pulmonary autograft.** *Lancet* 1967;7523:956–958. **(480; 10; 100)**
83	Daniel WG, Mügge A, Martin RP, Lindert O, Hausmann D, Nonnast-Daniel B, Laas J, Lichtlen PR. **Improvement in the diagnosis of abscesses associated with endocarditis by transesophageal echocardiography.** *New Engl J Med* 1991;12:795–800. **(477; 19; 92)**
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85	Schade R, Andersohn F, Suissa S, Haverkamp W, Garbe E. **Dopamine agonists and the risk of cardiac-valve regurgitation.** *New Engl J Med* 2007;1:29–38. **(474; 53; 53)**
86	Freeman RV, Otto CM. **Spectrum of calcific aortic valve disease: Pathogenesis, disease progression, and treatment strategies.** *Circulation* 2005;24:3316–3326. **(474; 43; 62)**
87	Rahimtoola SH. **The problem of valve prosthesis-patient mismatch.** *Circulation* 1978;1:20–24. **(472; 12; 97)**
88	Leon MB, Piazza N, Nikolsky E, Blackstone EH, Cutlip DE, Kappetein AP, Krucoff MW, MacK M, Mehran R, Miller C, Morel M-, Petersen J, Popma JJ, Takkenberg JJM, Vahanian A, Van Es G-, Vranckx P, Webb JG, Windecker S, Serruys PW. **Standardized endpoint definitions for transcatheter aortic valve implantation clinical trials: A consensus report from the valve academic research consortium.** *J Am Coll Cardiol* 2011;3:253–269. **(469; 94; 27)**
89	Alfieri O, Maisano F, De Bonis M, Stefano PL, Torracca L, Oppizzi M, La Canna G, Miller DC. **The double-orifice technique in mitral valve repair: A simple solution for complex problems.** *J Thorac Cardiovasc Surg* 2001;4:674–681. **(469; 31; 76)**
90	Yiu SF, Enriquez-Sarano M, Tribouilloy C, Seward JB, Tajik AJ. **Determinants of the degree of functional mitral regurgitation in patients with systolic left ventricular dysfunction: A quantitative clinical study.** *Circulation* 2000;12:1400–1406. **(467; 29; 79)**
91	Webb JG, Altwegg L, Boone RH, Cheung A, Ye J, Lichtenstein S, Lee M, Masson JB, Thompson C, Moss R, Carere R, Munt B, Nietlispach F, Humphries K. **Transcatheter aortic valve implantation: Impact on clinical and valve-related outcomes.** *Circulation* 2009;23:3009–3016. **(456; 65; 37)**

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Rank	Article
92	Feldman T, Kar S, Rinaldi M, Fail P, Hermiller J, Smalling R, Whitlow PL, Gray W, Low R, Herrmann HC, Lim S, Foster E, Glower D. **Percutaneous mitral repair with the MitraClip system. safety and midterm durability in the initial EVEREST (Endovascular Valve Edge-to-Edge REpair Study) cohort.** *J Am Coll Cardiol* 2009;8:686–694. **(454; 65; 38)**
93	Lamas GA, Mitchell GF, Flaker GC, Smith Jr. SC, Gersh BJ, Basta L, Moyé L, Braunwald E, Pfeffer MA. **Clinical significance of mitral regurgitation after acute myocardial infarction.** *Circulation* 1997;3:827–833. **(452; 24; 91)**
94	Walther T, Simon P, Dewey T, Wimmer-Greinecker G, Falk V, Kasimir MT, Doss M, Borger MA, Schuler G, Glogar D, Fehske W, Wolner E, Mohr FW, Mack M. **Transapical minimally invasive aortic valve implantation: Multicenter experience.** *Circulation* 2007;11 SUPPL. 1:I240-245. **(449; 50; 55)**
95	Baumgartner H, Hung J, Bermejo J, Chambers JB, Evangelista A, Griffin BP, Iung B, Otto CM, Pellikka PA, Quiñones M. **Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice.** *Eur J Echocardiogr* 2009;1:1–25. **(448; 64; 40)**
96	Lichtenstein SV, Cheung A, Ye J, Thompson CR, Carere RG, Pasupati S, Webb JG. **Transapical transcatheter aortic valve implantation in humans: Initial clinical experience.** *Circulation* 2006;6:591–596. **(446; 47; 59)**
97	Zoghbi WA, Chambers JB, Dumesnil JG, Foster E, Gottdiener JS, Grayburn PA, Khandheria BK, Levine RA, Marx GR, Miller Jr. FA, Nakatani S, Quiñones MA, Rakowski H, Rodriguez LL, Swaminathan M, Waggoner AD, Weissman NJ, Zabalgoitia M. **Recommendations for evaluation of prosthetic valves with echocardiography and Doppler ultrasound. A report from the American Society of Echocardiography's guidelines and standards committee and the task force on prosthetic valves, developed in conjunction with the American College of Cardiology Cardiovascular Imaging Committee, Cardiac Imaging Committee of the American Heart Association.** *J Am Soc Echocardiogr* 2009;9:975–1014. **(445; 64; 41)**
98	Singh JP, Evans JC, Levy D, Larson MG, Freed LA, Fuller DL, Lehman B, Benjamin EJ. **Prevalence and clinical determinants of mitral, tricuspid, and aortic regurgitation (the Framingham Heart Study).** *Am J Cardiol* 1999;6:897–902. **(443; 26; 86)**
99	Kappetein AP, Head SJ, Généreux P, Piazza N, Van Mieghem NM, Blackstone EH, Brott TG, Cohen DJ, Cutlip DE, Van Es G-, Hahn RT, Kirtane AJ, Krucoff MW, Kodali S, MacK MJ, Mehran R, Rodés-Cabau J, Vranckx P, Webb JG, Windecker S, Serruys PW, Leon MB. **Updated standardized endpoint definitions for transcatheter aortic valve implantation: The valve academic research consortium-2 consensus document.** *J Am Coll Cardiol* 2012;15:1438–1454. **(441; 110; 20)**
100	Zahn R, Gerckens U, Grube E, Linke A, Sievert H, Eggebrecht H, Hambrecht R, Sack S, Hauptmann KE, Richardt G, Figulla H-, Senges J. **Transcatheter aortic valve implantation: First results from a multi-centre real-world registry.** *Eur Heart J* 2011;2:198–204. **(438; 88; 29)**

Numbers in brackets, from left to right, represent: Citations, Citations per year and Rank according to citations per year.

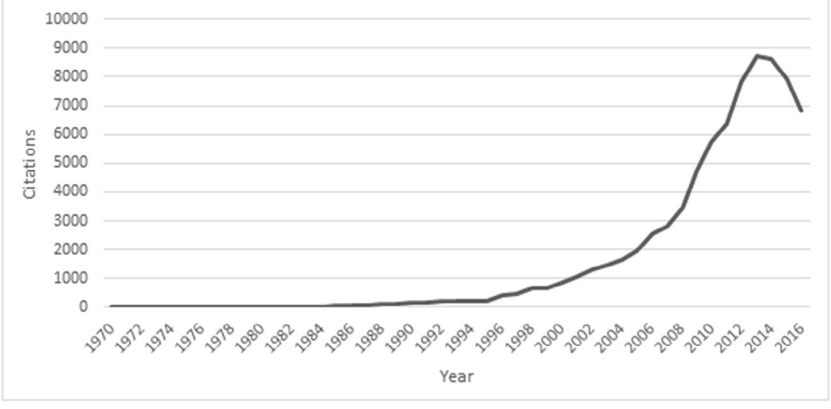

Figure 1. Total citations of all articles in the top-cited list each year.

can explain the relatively recent peaks seen in Figure 2. Figure 2 also demonstrates that older articles were not heavily favored due to the impact of citations accumulated over time. "Obliteration by inclusion," a concept described in 1987 by Garfield, can be a possible explanation.[14] This notion explains that the information within articles is less referenced and considered general knowledge as it becomes more accepted and incorporated into the scientific community. Figure 1 supports the previous assessment that research in VHD has recently taken off. The figure shows how articles studying

Table 2
Authors with 6 or more articles

Author	Total articles	First Position	Last Position	Other Positions	H index
Leon, M.B.	13	2	5	6	136
Otto, C.M.	12	3	2	7	55
Webb, J.G.	11	3	1	7	84
Vahanian, A.	8	3	2	3	77
Iung, B.	6	2	0	4	49

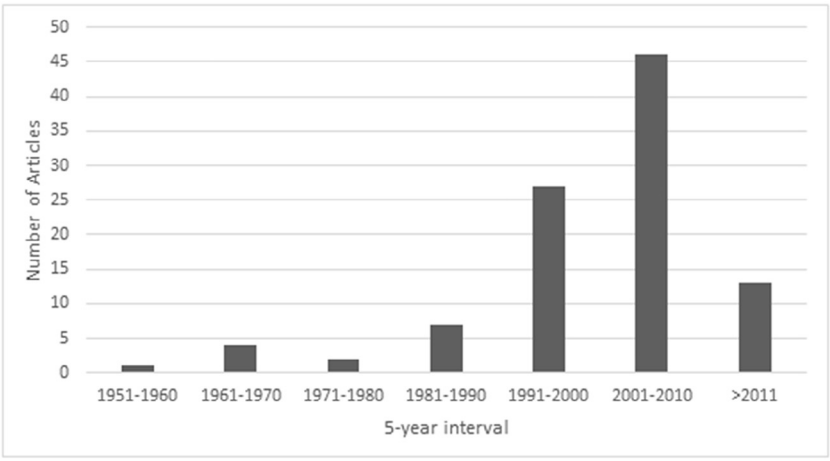

Figure 2. Number of publications in each 10-year interval.

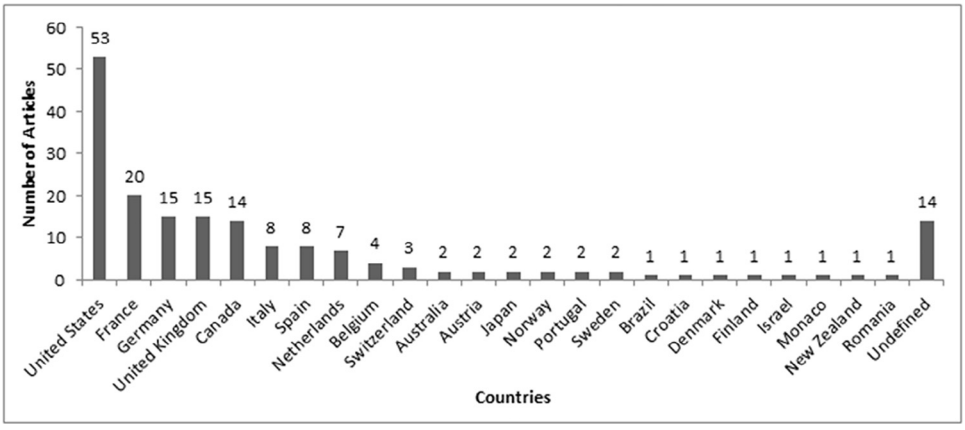

Figure 3. Number of articles originating from each country.

Table 3
Journals with 3 or more articles

Journal	Documents	2015 Impact Factor
Circulation	27	17.2
New England Journal of Medicine	19	59.56
Journal of American College of Cardiology	16	17.76
European Heart Journal	8	15.06
Journal of Thoracic and cardiovascular surgery	4	3.49
Lancet	4	44
Journal of American Medical Association	3	37.68
Journal of the American Society of Echocardiography	3	4.25

Table 4
Article descriptors

	Description	Frequency
Valve studied	All	43
	Aortic	39
	Mitral	11
	Pulmonary	3
	Tricuspid	4
Primary aim	Treatment	40
	Prognosis	14
	Prevalence	7
	Diagnosis	15
	Prevention	2
	Causes	11
	Other	11

VHD began receiving increased citations from 1996 onward. Research activity in the field peaked as recently as 2013.

Citation count serves as an effective indicator of the overall impact of an article in the scientific community. However, citation count gives no idea of the current influence of an article. To estimate the impact of an article in today's date, we included the variable "citations per year" in Table 1. Both categories (total citations and citations per year) were topped by the same article, "Transcatheter Aortic-Valve Implantation for Aortic Stenosis in Patients Who Cannot Undergo Surgery," authored by M.B. Leon et al, and published in the *New England Journal of Medicine*.

Our analysis outlines that the 100 most cited articles were published in 20 journals. Sixty-seven of the total articles were published in cardiology specialty journals, which is hardly surprising, as VHDs are particularly of interest to cardiologists,

and not so much to a general medicine audience. Overall, the trend of our bibliometrics supports the application of the Bradford law; a notion suggested by Brookes in 1969.[15] In essence, this law proposes that there are few core journals in respective fields of specialty from which a majority of researchers acquire their citations. Citation frequency and influence are weakened when these researchers diverge from these main journals; hence, this finding leads to a vast majority of the articles originating from the few core journals.[5,6] In our case, those core journals were *Circulation*, *New England Journal of Medicine*, and *Journal of American College of Cardiology*. Furthermore, we established that 6 of the top 10 cited articles were published in cardiology-specific journals. This finding outlines a growing pattern of publishing highly influential articles in specialty journals compared with other high-impact factor journals. Other bibliometrics also incline to support this concept.[3,16] This concept, and the lack of a significant correlation between the impact factor of a journal and the number of articles of that journal in the top 100 list, supports the argument that high-quality scientific work will have an impact—regardless of the journal the work is published in.

A few interesting observations can be made in regard to authors identified to have the greatest influence in the field of VHD. We identified 5 authors who had 6 or more citations in our list of 100 most cited articles. These eminent researchers can be considered the forerunners in VHD research. It is important to consider that those scientists who make notable contributions to literature have a higher chance to receive academic promotion, and editors are more likely to welcome their work and to ask them for reviews.[17] Furthermore, of the 770 authors who contributed to our top 100 cited articles, 220 had more than 2 citations. This finding outlines a large number of collaborations among investigators in this field. However, this collaboration could also be a cause of self-citations, which can cause bias in bibliometrics.

The United States contributed the largest number of articles (n = 53). Following by a wide gap are European countries and Canada. Insignificant contributions were made by Asian countries. An interesting point to be noted is that 22% of the articles originated from multiple countries. This is evidence that cooperation among countries can result in quality output that is of consideration within the scientific community.

We observed that a vast number of top-cited VHD articles focused on several subtopics ranging from the diagnosis and the epidemiology of VHD to the treatment and the prognosis. Distinguishing different areas of study is important so that researchers can publish productively in the future in areas where research is required. It also has significant implications for editors and stakeholders in selecting and judging future scientific work. Fifty-four percent of the articles studied either the treatment or the prognosis, of which about half (n = 25) focused on the safety and the efficacy of transcatheter aortic valve replacement (TAVR). The mean citation per year of TAVR articles was 133 (much higher than the overall citations-per-year average of 80), a clear indication that TAVR is currently a topic of interest to researchers. It follows that funding into TAVR research at this time is likely to yield impactful studies. Only 3 studies dealing with the percutaneous treatment of mitral valve defects were present in the top 100 list; however, ongoing studies such as the "Cardiovascular Outcomes Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients With Functional Mitral Regurgitation" (CO-APT) indicate that this area has the potential to receive increased attention in the future, and more studies on percutaneous valve repair may be identified by future bibliometrics. Only a few articles (n = 9) in the list studied the prevention and the prevalence of VHD. With the predicted increase in VHD due to an aging population, more research attention is needed toward studies that identify methods of prevention.

Although best efforts were made to eliminate bias, several limitations should be taken into account. Firstly, it has been reported that Scopus tends to miss older citations, which can possibly result in an omission of articles before 1980 from our top-cited list.[9,18] Moreover, our methods did not include textbooks, which could also result in omission bias. Secondly, 7.5% of the total citations received by the top 100 articles were author self-citations, which is above the average in the field of general medicine (6.5%).[19] Hence, we concluded that self-citations could be a source of bias. This was expected considering the numerous collaborations among the authors noted in our study. Thirdly, some of the recently published landmark articles might have not made it to the list as new articles take time to accumulate citations.[20] Citation frequency is a good indicator of the impact and reach of an article, but does not give us any idea of the quality of the study. As a result, some scientists propose the use of citation analysis along with more qualitative methods (such as analysis of the methodological quality) to get a more holistic idea of the scientific importance of an article.[2]

Disclosures

Dr. Khosa is the recipient of the Canadian Association of Radiologists/Canadian Radiological Foundation Leadership Scholarship (2017). The authors have no relevant disclosures. There was no commercial funding for this study.

1. d'Arcy JL, Prendergast BD, Chambers JB, Ray SG, Bridgewater B. Valvular heart disease: the next cardiac epidemic. *Heart* 2011;97:91–93.
2. Moed HF. The impact-factors debate: the ISI's uses and limits. *Nature* 2002;415:731–732.
3. Brandt JS, Downing AC, Howard DL, Kofinas JD, Chasen ST. Citation classics in obstetrics and gynecology: the 100 most frequently cited journal articles in the last 50 years. *Am J Obstet Gynecol* 2010;203:355, e351-357.
4. Paladugu R, Schein M, Gardezi S, Wise L. One hundred citation classics in general surgical journals. *World J Surg* 2002;26:1099–1105.
5. Lefaivre KA, Shadgan B, O'Brien PJ. 100 most cited articles in orthopaedic surgery. *Clin Orthop Relat Res* 2011;469:1487–1497.
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