Bibliometric Analysis of the Top 100 Cited Cardiovascular Articles

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The number of citations an article receives is an important indication of its impact and contribution to the clinical world. There is a paucity of literature concerning top article citations in cardiology. The main objective of this investigation was to bridge this gap and to provide readers a practical guide in evaluating the cardiovascular literature. Scopus Library database was searched to determine the citations of all published cardiovascular articles. One hundred two journals were included in our investigation under the Institute of Science Information Web of Science subject category "cardiology, cardiovascular, and heart." We did not apply any time or study-type restriction in our search. The top 100 cited articles were selected and analyzed by 2 independent investigators. The journal with the highest number of top 100 cited articles was *Circulation* with 36, followed by 28 in the *European Heart Journal*. A statistically significant association was found between the journal impact factor and the number of top 100 cited articles ($p < 0.005$). United States had the highest number of articles (49). Contrary to bibliometric analyses published in other medical fields, the largest subset of the cardiology articles ($n = 42$) was published in the 5-year period from 2006 to 2010. General medical journals such as *The Lancet* ($n = 4$) and *The New England Journal of Medicine* ($n = 1$) contributed only 5 articles to the list despite their extremely high impact factors. In conclusion, our analysis provides an insight on the citation frequency of top cited articles published in cardiovascular medicine to help recognize the quality of the works, discoveries, and the trends steering cardiology. **(Am J Cardiol 2015;115:972−981)**

Academic institutions, public and private funding sectors, are now more interested in assessing the quality and productivity of individual scholarly work as a parameter for measuring the academic excellence to prioritize resources and reorient support. Bibliometric techniques are a powerful tool in performing citation analysis, one of the markers of the impact of an individual's scholarly work within the scientific community.[1] Although the value of citation rates has been debated,[2] analysis of citation frequency can be valuable in identifying important issues and discoveries within the medical realm. Cardiology has evolved substantially in the last few decades. However, there is a paucity of literature concerning top article citations in cardiology. The main objective of our investigation is to bridge this gap and provide for the readers a practical guide to evaluate impact within the cardiovascular literature.

Methods

In September 2014, we searched the Scopus Library database (*www.scopus.com*) for citations of published cardiovascular articles. One hundred seven journals were included in our investigation under the Institute of Science Information Web of Science subject category "cardiology, cardiovascular, and heart." In this list, *Stroke*, *Statistics in Medicine, Diabetes Care*, *Autoimmunity Reviews, and Anesthesia and Analgesia* were not consistent with the focus of our investigation and, hence, excluded. No time limitations were implemented on the investigation. Also, we did not impose any restriction on the basis of study types, availability of an abstract, and human versus nonhuman research subjects.

The remaining 102 journals were searched using both electronic and print International Standard Serial Numbers. The list of journals identified was exported into a spreadsheet. All identified journals were collected in a single search in Web of Science. Our search yielded a list of all indexed published articles in each of the journals. The results were arranged using the option "Times cited" that provided us a list of the all the articles published in a specific journal ranked by citation counts. The results were then evaluated by 2 independent investigators to conclude the 100 top cited articles. Later we also individually cataloged the articles in a database for further categorization.

Using the modified approach of the methods by Lim et al,[3] 2 authors reviewed the 100 articles and the following data were compiled: number of authors, publication year, journal name, impact factor, country of origin, where the investigation was conducted, and article type (original and review articles). We also reviewed the association between journal impact factor and the number of articles included in

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See page 981 for disclosure information.

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Table 1
List of 100 most cited cardiovascular articles

Rank	Article	Citations
1.	Mancia G, De Backer G, Dominiczak A, Cifkova R, Fagard R, Germano G,Grassi G, Heagerty AM, Kjeldsen SE, Laurent S, Narkiewicz K, Ruilope L, Rynkiewicz A, Schmieder RE, Boudier HA, Zanchetti A, Vahanian A, Camm J, De Caterina R, Dean V, Dickstein K, Filippatos G, Funck-Brentano C, Hellemans I, Kristensen SD, McGregor K, Sechtem U, Silber S, Tendera M, Widimsky P, Zamorano JL, Erdine S, Kiowski W, Agabiti-Rosei E, Ambrosioni E, Lindholm LH, Viigimaa M, Adamopoulos S, Agabiti-Rosei E, Ambrosioni E, Bertomeu V, Clement D, Erdine S, Farsang C, Gaita D, Lip G, Mallion JM, Manolis AJ, Nilsson PM, O'Brien E, Ponikowski P, Redon J, Ruschitzka F, Tamargo J, van Zweiten P, Waeber B, Williams B. 2007 Guidelines for the Management of Arterial Hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *J Hypertens* 2007;25:1105-1187.	3484
2.	Zanchetti A. 2003 European Society of Hypertension-European Society of Cardiology guidelines for the management of arterial hypertension. *J Hypertens* 2003;21:1011-1053.	3043
3.	Conroy RM, Pyörälä K, Fitzgerald AP, Sans S, Menotti A, De Backer G, De Bacquer D, Ducimetiere P, Jousilahti P, Keil U, Njolstad I, Oganov RG, Thomsen T, Tunstall-Pedoe H, Tverdal A, Wedel H, Whincup P, Wilhelmsen L, Graham IM. Estimation of ten-year risk of fatal cardiovascular disease in Europe: The SCORE project. *Eur Heart J* 2003;24:987-1003.	2046
4.	Malliani A, Pagani M, Lombardi F, Cerutti S. Cardiovascular neural regulation explored in the frequency domain. *Circulation* 1991;84:482-492.	1956
5.	Dickstein K, Cohen-Solal A, Filippatos G, McMurray JJV, Ponikowski P, Poole-Wilson PA, Stromberg A, van Veldhuisen DJ, Atar D, Hoes AW, Keren A, Mebazaa A, Nieminen M, Priori SG, Swedberg K. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2008. *Eur Heart J* 2008;29:2388-2442.	1903
6.	Camm AJ, Kirchhof P, Lip GYH, Schotten U, Savelieva I, Ernst S, Van Gelder IC, Al-Attar N, Hindricks G, Prendergast B, Heidbuchel H, Alfieri O, Angelini A, Atar D, Colonna P, De Caterina R, De Sutter J, Goette A, Gorenek B, Heldal M, Hohloser SH, Kolh P, Le Heuzey JY, Ponikowski P, Rutten FH. Guidelines for the management of atrial fibrillation. *Eur Heart J* 2010;31:2369-2429.	1874
7.	Van De Werf F, Bax J, Betriu A, Blomstrom-Lundqvist C, Crea F, Falk V, Filippatos G, Fox K, Huber K, Kastrati A, Rosengren A, Steg PG, Tubaro M, Verheugt F. Management of acute myocardial infarction in patients presenting with persistent ST-segment elevation. *Eur Heart J*. 2008;29:2909-2945.	1673
8.	Sarnak MJ, Levey AS, Schoolwerth AC, Coresh J, Culleton B, Hamm LL, McCullough PA, Kasiske BL, Kelepouris E, Klag MJ, Parfrey P, Pfeffer M, Raij L, Spinosa DJ, Wilson PW. Kidney Disease as a Risk Factor for Development of Cardiovascular Disease: A Statement From the American Heart Association Councils on Kidney in Cardiovascular Disease, High Blood Pressure Research, Clinical Cardiology, and Epidemiology and Prevention. *Circulation* 2003;108:2154-2169.	1618
9.	Vahanian A, Baumgartner H, Bax J, Butchart E, Dion R, Filippatos G, Flachskampf F, Hall R, Iung 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;28:230-268.	1433
10.	Danesh J, Collins R, Appleby P, Peto R. Association of fibrinogen, C-reactive protein, albumin, or leukocyte count with coronary heart disease: Meta-analyses of prospective studies. *JAMA* 1998;279:1477-1482.	1362
11.	Beckman JA, Creager MA, Libby P. Diabetes and atherosclerosis epidemiology, pathophysiology, and management. *JAMA* 2002;287:2570-2581.	1314
12.	Bonow RO, Carabello BA, Kanu C, De Leon AC Jr, Faxon DP, Freed MD, Gaasch WH, Lytle BW, Nishimura RA, O'Gara PT, O'Rourke RA, Otto CM, Shah PM, Shanewise JS, Smith SC Jr, Jacobs AK, Adams CD, Anderson JL, Antman EM, Faxon DP, Fuster V, Halperin JL, Hiratzka LF, Hunt SA, Lytle BW, Nishimura R, Page RL, Riegel B. 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;114:e84-e231.	1226
13.	Rydén L, Standl E, Małgorzata B, Van Den Berghe G, Betteridge J, De Boer MJ, Cosentino F, Jönsson B, Laakso M, Malmberg K, Priori S, Ostergren J, Tuomilehto J, Thrainsdottir I, Vanhorebeek I, Stramba-Badiale M, Lindgren P, Qiao Q, Priori SG, Blanc JJ, Budaj A, Camm J, Dean V, Deckers J, Dickstein K, Lekakis J, McGregor K, Metra M, Morais J, Osterspey A, Tamargo J, Zamorano JL, Deckers JW, Bertrand M, Charbonnel B, Erdmann E, Ferrannini E, Flyvbjerg A, Gohlke H, Juanatey JR, Graham I, Monteiro PF, Parhofer K, Pyörälä K, Raz I, Schernthaner G, Volpe M, Wood D. Guidelines on diabetes, pre-diabetes, and cardiovascular diseases: Executive summary. The task force on diabetes and cardiovascular diseases of the European Society of Cardiology (ESC) and of the European Association for the Study of Diabetes (EASD). *Eur Heart J* 2007;28:88-136.	1095
14.	Dickstein K, Cohen-Solal A, Filippatos G, McMurray JJ, Ponikowski P, Poole-Wilson PA, Strömberg A, van Veldhuisen DJ, Atar D, Hoes AW, Keren A, Mebazaa A, Nieminen M, Priori SG, Swedberg K. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2008. The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM). *Eur J Heart Fail* 2008;10:933-989.	1043
15.	Antman EM, Anbe DT, Armstrong PW, Bates ER, Green LA, Hand M, Hochman JS, Krumholz HM, Kushner FG, Lamas GA, Mullany CJ, Ornato JP, Pearle DL, Sloan MA, Smith SC Jr, Alpert JS, Anderson JL, Faxon DP, Fuster V, Gibbons RJ, Gregoratos G, Halperin JL, Hiratzka LF, Hunt SA, Jacobs AK. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction - Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (writing committee to revise the 1999 guidelines for the management of patients with acute myocardial infarction). *Circulation* 2004;110:588-636.	935

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Rank	Article	Citations
16.	Graham I, Atar D, Borch-Johnsen K, Boysen G, Burell G, Cifkova R, Dallongeville J, De Backer G, Ebrahim S, Gjelsvik B, Herrmann-Lingen C, Hoes A, Humphries S, Knapton M, Perk J, Priori SG, Pyorala K, Reiner Z, Ruilope L, Sans-Menendez S, Scholte op Reimer W, Weissberg P, Wood D, Yarnell J, Zamorano JL, Walma E, Fitzgerald T, Cooney MT, Dudina A. European guidelines on cardiovascular disease prevention in clinical practice: Executive summary - Fourth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (Constituted by representatives of nine societies and by invited experts). *Eur Heart J* 2007;28:2375-414.	924
17.	Nagase H, Visse R, Murphy G. Structure and function of matrix metalloproteinases and TIMPs. *Cardiovasc Res*. 2006;69:562-573.	911
18.	Glassman AH, O'Connor CM, Califf RM, Swedberg K, Schwartz P, Bigger Jr JT, Krishnan KR, van Zyl LT, Swenson JR, Finkel MS, Landau C, Shapiro PA, Pepine CJ, Mardekian J, Harrison WM, Barton D, Mclvor M. Sertraline treatment of major depression in patients with acute MI or unstable angina. *JAMA* 2002;288:701-709.	905
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21.	Hunt SA, Abraham WT, Chin MH, Feldman AM, Francis GS, Ganiats TG, Jessup M, Konstam MA, Mancini DM, Michl K, Oates JA, Rahko PS, Silver MA, Stevenson LW, Yancy CW. 2009 focused update incorporated into the ACC/AHA 2005 guidelines for the diagnosis and management of heart failure in adults: A report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines: Developed in collaboration with the International Society for Heart and Lung Transplantation. *Circulation* 2009;119:e391-e479.	822
22.	Nieminen MS, Böhm M, Cowie MR, Drexler H, Filippatos GS, Jondeau G, Hasin Y, Lopez-Sendon J, Mebazaa A, Metra M, Rhodes A, Swedberg K, Priori SG, Garcia MA, Blanc JJ, Budaj A, Cowie MR, Dean V, Deckers J, Burgos EF, Lekakis J, Lindahl B, Mazzotta G, Morais J, Oto A, Smiseth OA, Garcia MA, Dickstein K, Albuquerque A, Conthe P, Crespo-Leiro M, Ferrari R, Follath F, Gavazzi A, Janssens U, Komajda M, Morais J, Moreno R, Singer M, Singh S, Tendera M, Thygesen K. Executive summary of the guidelines on the diagnosis and treatment of acute heart failure: The Task Force on Acute Heart Failure of the European Society of Cardiology. Eur Heart J 2005;26:384-416.	821
23.	Ellis SG, Vandormael MG, Cowley MJ, DiSciascio G, Deligonul U, Topol EJ, Bulle TM. Coronary morphologic and clinical determinants of procedural outcome with angioplasty for multivessel coronary disease: Implications for patient selection. *Circulation* 1990;82:1193-202.	810
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26.	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;116:1736-1754.	777
27.	Cleland JGF, Swedberg K, Follath F, Komajda M, Cohen-Solal A, Aguilar JC, Dietz R, Gavazzi A, Hobbs R, Korewicki J, Madeira HC, Moiseyev VS, Preda I, van Gilst WH, Widimsky J, Freemantle N, Eastaugh J, Mason J. The EuroHeart Failure survey programme - A survey on the quality of care among patients with heart failure in Europe. Part 1: Patient characteristics and diagnosis. *Eur Heart J* 2003;24:442-463.	769
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30.	Grundy SM, Pasternak R, Greenland P, Smith Jr S, Fuster V. Assessment of cardiovascular risk by use of multiple-risk-factor assessment equations: A statement for healthcare professionals from the American Heart Association and the American College of Cardiology. *Circulation* 1999;100:1481-1492.	728
31.	Hunt SA, Abraham WT, Chin MH, Feldman AM, Francis GS, Ganiats TG, Jessup M, Konstam MA, Mancini DM, Michl K, Oates JA, Rahko PS, Silver MA, Stevenson LW, Yancy CW. 2009 Focused Update Incorporated Into the ACC/AHA 2005 Guidelines for the Diagnosis and Management of Heart Failure in Adults. A Report of the American College of Cardiology Foundation/ American Heart Association Task Force on Practice Guidelines Developed in Collaboration With the International Society for Heart and Lung Transplantation. *J Am Coll Cardiol* 2009;53:e1-e90.	724
32.	Braunwald E, Antman EM, Beasley JW, Califf RM, Cheitlin MD, Hochman JS, Jones RH, Kereiakes D, Kupersmith J, Levin TN, Pepine CJ, Schaeffer JW, Smith EE 3rd, Steward DE, Theroux P, Gibbons RJ, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Smith SC Jr. ACC/AHA guideline update for the management of patients with unstable angina and non-ST-segment elevation myocardial infarction - 2002: Summary article: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on the Management of Patients with Unstable Angina). *Circulation* 2002;106:1893-1900.	719
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34.	Anderson LJ, Holden S, Davis B, Prescott E, Charrier CC, Bunce NH, Firmin DN, Wonke B, Porter J, Walker JM, Pennell DJ. Cardiovascular T2-star (T2*) magnetic resonance for the early diagnosis of myocardial iron overload. *Eur Heart J* 2001;22:2171-2179.	713
35.	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. 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): endorsed by the Society of Cardiovascular. *Circulation* 2008;118:e523-661.	695
36.	Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr, Gibbons RJ, Antman EM, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Russell RO, Smith SC Jr. ACC/AHA 2002 guideline update for exercise testing: Summary article. A report of the American College of Cardiology/American Heart Association task force on practice guidelines (committee to update the 1997 exercise testing guidelines). *Circulation* 2002;106:1883-1892.	673
37.	Camm AJ, Lip GY, De Caterina R, Savelieva I, Atar D, Hohnloser SH, Hindricks G, Kirchhof P. 2012 focused update of the ESC Guidelines for the management of atrial fibrillation. *Eur Heart J* 2012;33:2719-2747.	658
38.	Libby P, Theroux P. Pathophysiology of coronary artery disease. *Circulation* 2005;111:3481-3488.	653
39.	Halestrap AP, Clarke SJ, Javadov SA. Mitochondrial permeability transition pore opening during myocardial reperfusion - A target for cardioprotection. *Cardiovasc Res* 2004;61:372-385.	630
40.	Moya A, Sutton R, Ammirati F, Blanc JJ, Brignole M, Dahm JB, Deharo JC, Gajek J, Gjesdal K, Krahn A, Massin M, Pepi M, Pezawas T, Ruiz Granell R, Sarasin F, Ungar A, van Dijk JG, Walma EP, Wieling W. Guidelines for the diagnosis and management of syncope (version 2009). *Eur Heart J* 2009;30:2631-2671.	629
41.	Sans S, Kesteloot H, Kromhout D. The burden of cardiovascular diseases mortality in Europe. Task Force of the European Society of Cardiology on Cardiovascular Mortality and Morbidity Statistics in Europe. *Eur Heart J* 1997;18:1231-1248.	613
42.	Gissi-HF Investigators, Tavazzi L, Maggioni AP, Marchioli R, Barlera S, Franzosi MG, Latini R, Lucci D, Nicolosi GL, Porcu M, Tognoni G. Effect of n-3 polyunsaturated fatty acids in patients with chronic heart failure (the GISSI-HF trial): a randomised, double-blind, placebo-controlled trial. *Lancet* 2008;372:1223-1230.	561
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44.	Ronco C, Haapio M, House AA, Anavekar N, Bellomo R. Cardiorenal Syndrome. *J Am Coll Cardiol* 2008;52:1527-1539.	540
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48.	Libby P, Ridker PM, Hansson GK. Inflammation in Atherosclerosis. From Pathophysiology to Practice. *J Am Coll Cardiol* 2009;54:2129-2138.	526
49.	Zipes DP, Camm AJ, Borggrefe M, Buxton AE, Chaitman B, Fromer M, Gregoratos G, Klein G, Moss AJ, Myerburg RJ, Priori SG, Quinones MA, Roden DM, Silka MJ, Tracy C, Smith SC Jr, Jacobs AK, Adams CD, Antman EM, Anderson JL, Hunt SA, Halperin JL, Nishimura R, Ornato JP, Page RL, Riegel B, Blanc JJ, Budaj A, Dean V, Deckers JW, Despres C, Dickstein K, Lekakis J, McGregor K, Metra M, Morais J, Osterspey A, Tamargo JL, Zamorano JL. ACC/AHA/ESC 2006 guidelines for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death: A report of the American College of Cardiology/American Heart Association Task Force and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Develop Guidelines for Management of Patients with Ventricular Arrhythmias and the. *Circulation* 2006;114:e385-e484.	523
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Rank	Article	Citations
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Rank	Article	Citations
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Table 1
(*continued*)

Rank	Article	Citations
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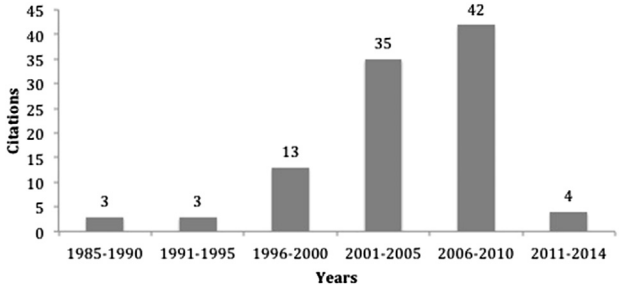

Figure 1. 5-Year interval for 100 top cited cardiovascular articles.

the top 100 articles. Only the journals with at least 1 top 100 cited articles were included in our investigation.

Using the Pearson product-moment correlation coefficient, we evaluated the strength and direction of the linear relation between the impact factor of the journal and the number of top 100 cited articles included in the list. The statistical software packages used for data analysis were Stata/MP 10.0 (Stata, College Station, Texas). Data are presented as medians and interquartile ranges. A significance level of $\alpha = 0.05$ was used for all the comparisons.

Results

The number of citations for the top 100 cited articles ranged from 331 to 3,484 (Table 1). The median number of citations was 515 (interquartile range 391.25). The median number of authors was 12 (interquartile range 13.25). The top 100 articles were published from 1985 to 2013, with most articles (n = 42) published in the 5-year period from 2006 to 2010 (Figure 1).

The journal with the highest number of top 100 cited articles was *Circulation*, with 36 (Table 2) followed by *European Heart Journal*, with 28. *Journal of the American Medical Association*, *Cardiovascular Research*, and *Journal of the American College of Cardiology* each had >5 highly cited articles. General medical journals such as *The Lancet* (n = 4) and *The New England Journal of Medicine* (n = 1) contributed only 5 articles to the list despite their extremely high impact factors. The impact factors for journals with the top 100 cited articles ranged from 2.443 to 54.42. We found a statistically significant association between journal impact factor and the number of top 100 cited articles ($p < 0.005$).

Table 2
Total articles according to journal and their impact factor

Journal	Total Articles	Impact Factor 2013
Circulation	36 (42,074)	14.94
European Heart Journal	28 (14,793)	14.72
Journal of the American Medical Association	8 (62,686)	29.98
Cardiovascular Research	6 (10,079)	5.808
Journal of the American College of Cardiology	6 (22,143)	14.09
The Lancet	4 (128,962)	39.20
Journal of Hypertension	3 (11,058)	4.22
European Journal of Cardiovascular Prevention and Rehabilitation	3 (958)	3.69
The American Journal of Cardiology	2 (35,262)	3.425
European Journal of Heart Failure	1 (2,458)	6.577
The New England Journal of Medicine	1 (71,098)	54.42
Hypertension	1 (9,658)	6.87
Progress in Cardiovascular Diseases	1 (1,986)	2.443

There were 13 different countries of origin for the highly cited articles. The United States had the largest number of articles, with 49. The United Kingdom published a total of 14 articles. All other countries had <10 highly cited articles. Three of the articles did not have the names of the authors listed as they were published by either medical societies or associations and, therefore, reported as not available (Figure 2). Sixty articles were review articles, whereas the other 40 were original articles (Figure 3).

Discussion

In our comprehensive list of the most highly cited articles in cardiovascular medicine, we found that the top 2 articles were guidelines regarding the management of arterial hypertension published by the European Society of Cardiology. Both these studies were the only articles to cross 3,000 citations. This is not surprising considering that hypertension is projected to effect 1.5 billion people in the next 10 years and is estimated to cause 9.4 million deaths annually.[4,5] These high numbers help to explain the pervasive public and medical interest generated by these guidelines. On further scrutiny, it can be observed that of the 14 articles with more than 1,000 citations, 8 were guideline

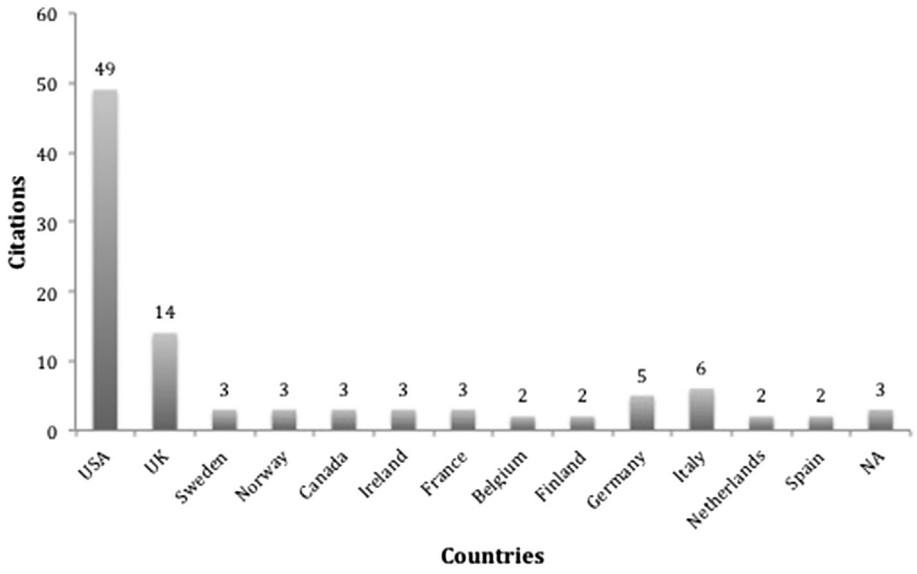

Figure 2. Articles according to country of origin.

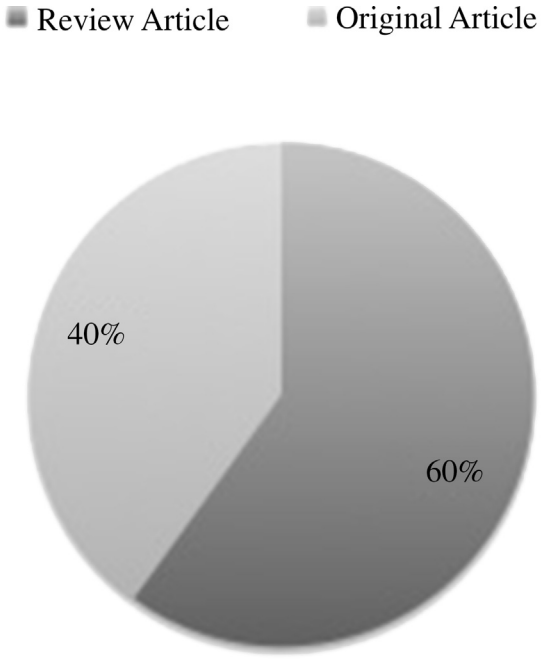

Figure 3. Type of manuscripts for 100 top cited cardiovascular articles.

oriented. This indicates that guidelines compared with basic science and individual clinical studies can have superior effect on readership.

Overall, it was observed that a large majority of the most highly cited articles in cardiovascular medicine focused on valvular heart disease and heart failure secondary to coronary artery disease. This can have important implications for the stakeholders and journal editors in selecting and evaluating scientific works in the field of cardiovascular medicine. It is also important to realize the possible effect of publication bias toward these articles and that cardiovascular literature is heavily tied to the pharmaceutical and device industries. Nonetheless, knowledge and understanding of the features inherent to highly cited work would help young researchers to publish effectively. However, we believe that this list also helps to point out the topics and subspecialties that have not been given due consideration. For instance, congenital heart diseases, coronary imaging, cardiac tumors, and cardiomyopathies were virtually nonexistent in the list. As the prevalence of congenital heart diseases is increasing dramatically,[6] we feel that this issue along with the earlier mentioned topics should have greater future representation in the list.

We found that the most highly cited articles were published in a variety of journals, 13 in all. More than half (n = 64) of these articles were published in the *Circulation* or *European Heart Journal*—both the journals are dedicated solely to the research of cardiovascular diseases and have an impact factor >14. Our findings support the application of Bradford's law, a bibliometric concept suggested by Brookes.[7,8] The principle idea behind Bradford's law is that most researchers obtain their citations from a few main journals in their respective field of expertise. When the researchers deviate from these core journals, their citation frequency and impact are weakened. Consequently, this tendency leads to a large percentage of citations stemming from a few core journals.[7,8]

Furthermore, the 2 most highly cited articles were published in a relatively low−impact factor journal (*Journal of Hypertension*). This indicates a growing trend of publishing highly influential articles in specialty journals compared with high−impact factor journals. Other bibliometric analyses also tend to support this notion.[9−11] *The New England Journal of Medicine and The Lancet*, 2 of the most high−impact factor journals, contributed just 5 articles to the list. Furthermore, in concordance with many other citation analyses, most of the studies that made the top 100 list were from the United States.[12−14]

We also demonstrate that most (n = 77) of the highly cited articles in cardiovascular medicine were of the period

2001 to 2010. This is contrary to most other bibliometric analyses, which generally found that the peak period for citation was from 1980 to 1995.[13,15] In fact in a citation classic of general surgery journals, the authors found that approximately 1/3 of the highly cited works were published before 1960.[14] This contradiction might be explained by the dynamic field of cardiovascular medicine in which the body of literature has flourished immensely in the past, and clinicians tend to rely on the latest guidelines. Having said that some elapsed time is needed for the articles to accumulate citations and gain significant coverage. This lack of elapsed time explains the relatively few top cited articles published during 2011 to 2014. Future bibliometric analyses can confirm this notion and help to better delineate the timeline associated with peak citation trends in cardiovascular medicine. In contrast, absence of any article before 1985 in the highly cited list suggests the limited usefulness of old articles in the modern era. However, it is important to realize that this trend could be because of a combination of many issues. Limitations in databases for tracking older articles, lack of online and internet resources in the pre-1990s, and the inclination toward publishing original contributions in textbooks rather than in manuscript forms might have all contributed to this downward trend.

As with any other bibliometric analyses, there are many potential limitations in this study. First, this type of study usually favors older published articles and omits landmark articles from the last 10 years.[16,17] However, in contrast, in this study, approximately 50% of the most highly cited articles in cardiovascular medicine were from the past 10 years. Second, there are potential shortcomings of the database used and exclusion of textbooks in this methodology. This might have resulted in omission of articles before 1980 as Scopus has been reported to miss older citations.[18,19] However, to ensure that our methodology was rigorous enough, we also included general medical journals such as *The New England Journal of Medicine* to avoid missing highly cited articles during our search. Third, the inherent problems associated with citation analyses, such as the bias linked to rely on the total number of times an article is cited, must be noted as well. Although minimal, self-citation was also not taken into consideration in our study. Lastly, we only used a single electronic medical database for our search. Keeping in mind the significant differences between various databases,[18,19] it is possible that our list of most highly cited articles might be different if we had used Google scholar or any other database instead of Scopus.

Disclosures

There are no conflicts of interests. There was no commercial funding for this study. The authors have full control over all the data. The study will not be published elsewhere in any language without the consent of the copyright owners.

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