Characteristics of Highly Cited Articles in Interventional Cardiology

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Citation classics have been published in many fields of medicine; however, none have focused on interventional cardiology. The goal of this study was to identify the top 100 articles in the field of interventional cardiology and highlight their important trends and characteristics. The Scopus database was used by 2 independent reviewers to extract the top 100 articles using a variety of keywords. We found articles published between 1953 and 2012. Majority (n = 78) of the top 100 articles were published between 1996 and 2010, and the United States was affiliated with the highest number of articles in our list (n = 68). Over half (n = 54) the articles were funded. Private funding was correlated with higher citations (p = 0.036). A third (n = 33) of the papers had authors with conflicts of interest; however, conflict of interest had no effect on citations (p = 0.837). Majority (n = 57) of the articles studied coronary angioplasty and stenting; followed by coronary angiography (n = 14). Women were underrepresented, with only 11 female first authors in the top 100 papers, and only 1 female in the list of top authors who had 5 or more publications. In conclusion, the following features define the typical highly cited article in interventional cardiology—a clinical trial conducted in the United States, which studies angioplasty, and has been published relatively recently in a high-impact journal by a male first author. **(Am J Cardiol 2017;120:2100–2109)**

Bibliometric analysis is a technique used to analyze published literature to study citation frequency and patterns. This method helps estimate the impact of articles within a field,[1,2] and is a powerful tool in helping direct research by highlighting problems and novel discoveries. Institutions can use this analysis to guide the utilization of their limited resources.[3] For example, it has been proposed that funding from the National Institutes of Health (NIH) has not been reaching the most influential scientists in the United States. A study has suggested channeling research funds to authors who have papers with extremely high citation counts.[4] Although controversial,[5] the utilization of such a method can effectively distribute NIH's multibillion dollar budget. Numerous studies have been conducted in various specialties and subspecialties to determine the characteristics of highly cited articles.[6–12] However, no such study has investigated the impact of funding source and conflict of interests on citations. Moreover, no citation classic has been performed in the field of interventional cardiology. Thus, the objective of this study was to present and analyze the 100 most cited articles in interventional cardiology and look at effect of study funding and conflict of interest on citations.

Methods

Scopus was selected as the database of choice for this study. Two independent reviewers (MSU and NH) independently carried out trial searches to identify several articles on interventional cardiology. All the articles were transferred to endnote, and repeating keywords were identified. With the consensus of all reviewers, the following keywords were selected for the search: "coronary angiogra*," "coronary angioplasty," "Percutaneous," "Percutaneous valv*," "Catheter," "Stent*," "atherectomy," "Transcatheter," "ablation," "coronary arteriography," "fractional flow reserve," "thrombectomy," "pacemaker insertion," and "defibrillator implant." A wildcard character (*) was used in appropriate places to account for spelling differences and plurals. Furthermore, common abbreviations, such as percutaneous coronary intervention (PCI), percutaneous transluminal coronary angioplasty (PTCA) and fractional flow reserve (FFR) were included. All the terms were searched for in the title, abstract, and keywords.

In the first week of March 2017, 2 investigators (MSU and NH) carried out the search and were blinded to the results of each other during the process. No time interval was set, and studies without abstract, studies in languages other than English, and nonhuman studies were considered as well. Original articles in the field of interventional cardiology were part of the inclusion criteria. These included, but were not limited to, studies on coronary angiography, angioplasty and stenting,

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carotid artery stenosis repair, percutaneous valve replacement, thrombectomy, valvuloplasty, and percutaneous valve repair. Selected articles were arranged using the "cited by" option, and lists from both reviewers were compared and any discrepancies were solved by discussion.

The selected articles were thoroughly analyzed to extract important information. The countries of all authors were taken into consideration when determining the origin of an article. The citations-per-year value was calculated for all articles. The journal impact factors were obtained from Institute of Scientific Information Journal Citation Reports. IBM SPSS Statistics (v23.0, International Business Machines, Chicago, IL) was used to run the Pearson product-moment correlation coefficient test to find the correlation between impact factor of the journal and the number of articles of the journal in the list. This software was also used to run the Mann-Whitney *U* test to find the association between the type of funding a study received and the number of citations it garnered. Chi-square test was used to study the association between presence of funding in a study and its outcome (significant/nonsignificant). Microsoft Excel 2016 was used to create charts and tables. A p value of lesser than 0.05 was considered significant in all cases.

Results

Table 1 lists the top 100 articles in the field of interventional cardiology. The mean number of citations of all 100 articles was 1,384 while the median was 1,123 (interquartile range 607). The median citations-per-year was 76 (interquartile range 64.7). The total citations of all articles equaled 138,992, and 5.97% of these were self-citations. Figure 1 shows how the total citations of these articles varied by year.

A total of 958 different authors contributed to the 100 articles, with a median of 10.5 authors per paper. Thirteen authors had 5 or more articles in the top 100 list, and only 1 of these was a female. These top authors are listed in Table 2. Eleven percent of the first authors in our list were females. All of the 13 top authors had received private funding, and had conflicts of interest in at least 1 of their articles in the list.

Several countries were affiliated with our articles (Figure 2). Twenty-six percent of the articles originated from multiple countries. The 100 articles were published between 1953 and 2012. Figure 3 shows the number of articles that originated in each 5-year interval. According to our analysis, 2001 to 2005 was the most productive research interval in this field. Cleveland Clinic Foundation was the institution affiliated with the most articles in our list (n = 14).

Only a small group of 12 journals contributed to the articles in our list. The top 5 journals are listed in Table 3, along with their impact factors. Majority (n = 57) of the articles studied coronary angioplasty and stenting; the next most studied area was coronary angiography (n = 14). Majority of the articles (n = 55) in our list were clinical trials. Cohorts (n = 17), cross-sectionals (n = 12), and paired studies (n = 8) were also noted.

Over half the original studies (n = 54) had received funding. Ten percent of the articles were funded by a nongovernmental organization or a hospital; 31% were funded by a private company; and 20% were government funded. Seven articles had received more than 1 type of funding. The company Johnson and Johnson (Cordis) had funded the most studies in the list (n = 11). Overall, the citations of funded studies did not vary significantly from nonfunded studies (p = 0.376). We further analyzed to see if type of funding affected citation count. Government or hospital funding had no significant effect on citation count (p = 0.264 and p = 0.183, respectively). On the other hand, studies that received private funding had significantly more citations than studies that did not (p = 0.036). Our analysis further revealed that 33% of the papers had authors with conflicts of interest. Among these papers, the average number of authors with conflicts of interest was 5.2. Conflicts of interest resulted in no significant effect on the citations of the paper (p = 0.837). Among the 83 articles that measured an outcome variable, 75% had positive/significant outcomes. We noted that funding had no effect on whether the outcome was significant or not (p = 0.946).

Discussion

We observed that just over half of the top 100 interventional cardiology articles received funding; yet, no relation was found between funding and the number of citations. Private funding was the most common type of funding among these articles. This interest of private companies in the field may be because cardiology is the second largest area in terms of sales for those manufacturing medical devices—accounting for approximately 42 billion dollars in 2014 alone.[13] Some concerns have been raised that the close relation between the medical devices industry and interventional cardiologists can result in problematic conflicts of interest when it comes to research[14]; however, in the top 100 articles, only a third had authors with conflicts of interest. Furthermore, conflict of interest had no significant effect on the impact of the paper. We also noted that articles receiving private funding had significantly higher citations—the reason for this remains unclear; however, it could be due to effective direction of funding. The effect of different types of funding on the impact of an article is very poorly studied, and larger studies are required in this area.

According to our analysis, funding had no impact on whether the outcome of a study was significant or not. This observation might simply be because very few negative or equivocal studies were present in our list (n = 21). It has been reported that studies with statistically significant results are more likely to be published, and are usually published in journals with higher impact factors than those studies finding no difference between the study groups.[15] This publication bias may be the reason why such few negative/equivocal studies made it to the top 100 list.

It was observed that a total of 13 authors contributed 5 or more articles to this list. This indicates that there are a group of eminent researchers publishing most of the influential research in interventional cardiology. This is a large number when compared with bibliometrics in other specialties.[16,17] However, only 1 of these top 13 authors was a female. Furthermore, only 11% of first authors were females, which points to a definite male dominance in this particular field. Such a disparity is not uncommon in medical academia, as a previous research highlighted that only 23.2% of first authors and 12.7% of senior authors of original research articles were females.

Table 1
Top 100 original articles in interventional cardiology, their citations, and citations-per-year

Rank	Article	Citations	Citations per year
1	Serruys PW, de Jaegere P, Kiemeneij F, Macaya C, Rutsch W, Heyndrickx G, Emanuelsson H, Marco J, Legrand V, Materne P, Belardi J, Sigwart U, Colombo A, Goy JJ, Van Den Heuvel P, Delcan J, Morel MA. **A comparison of balloon-expandable-stent implantation with balloon angioplasty in patients with coronary artery disease.** *New Eng J Med* 1994;331:489–495.	3932	171
2	Fischman DL, Leon MB, Baim DS, Schatz RA, Savage MP, Penn I, Detre K, Veltri L, Ricci D, Nobuyoshi M, Cleman M, Heuser R, Almond D, Teirstein PS, Fish RD, Colombo A, Brinker J, Moses J, Shaknovich A, Hirshfeld J, Bailey S, Ellis S, Rake R, Goldberg S. **A randomized comparison of coronary-stent placement and balloon angioplasty in the treatment of coronary artery disease.** *New Eng J Med* 1994;331:496–501.	3732	162
3	Moses JW, Leon MB, Popma JJ, Fitzgerald PJ, Holmes DR, O'Shaughnessy C, Caputo RP, Kereiakes DJ, Williams DO, Teirstein PS, Jaeger JL, Kuntz RE. **Sirolimus-eluting stents versus standard stents in patients with stenosis in a native coronary artery.** *New Eng J Med* 2003;349:1315–1323.	3575	255
4	Morice MC, Serruys PW, Eduardo Sousa J, Fajadet J, Hayashi EB, Perin M, Colombo A, Schuler G, Barragan P, Guagliumi G, Molnàr F, Falotico R. **A randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization.** *New Eng J Med* 2002;346:1773–1780.	3395	226
5	Moss AJ, Jackson Hall W, Cannom DS, Daubert JP, Higgins SL, Klein H, Levine JH, Saksena S, Waldo AL, Wilber D, Brown MW, Heo M. **Improved survival with an implanted defibrillator in patients with coronary disease at high risk for ventricular arrhythmia.** *New Eng J Med* 1996;335:1933–1940.	2930	140
6	Keeley EC, Boura JA, Grines CL. **Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: A quantitative review of 23 randomised trials.** *Lancet* 2003;361:13–20.	2796	200
7	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. **Transcatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery.** *New Eng J Med* 2010;363:1597–1607.	2770	396
8	Steinhubl SR, Berger PB, Tift Mann Iii J, Fry ETA, DeLago A, Wilmer C, Topol EJ. **Early and sustained dual oral antiplatelet therapy following percutaneous coronary intervention: A randomized controlled trial.** *JAMA* 2002;288:2411–2420.	2572	171
9	Mehta SR, Yusuf S, Peters RJG, Bertrand ME, Lewis BS, Natarajan MK, Malmberg K, Rupprecht HJ, Zhao F, Chrolavicius S, Copland I, Fox KAA. **Effects of pretreatment with clopidogrel and aspirin followed by long-term therapy in patients undergoing percutaneous coronary intervention: The PCI-CURE study.** *Lancet* 2001;358:527–533.	2571	161
10	Iakovou I, Schmidt T, Bonizzoni E, Ge L, Sangiorgi GM, Stankovic G, Airoldi F, Chieffo A, Montorfano M, Carlino M, Michev I, Corvaja N, Briguori C, Gerckens U, Grube E, Colombo A. **Incidence, predictors and outcome of thrombosis after successful implantation of drug-eluting stents.** *JAMA* 2005;293:2126–2130.	2473	206
11	Boden WE, O'Rourke RA, Teo KK, Hartigan PM, Maron DJ, Kostuk WJ, Knudtson M, Dada M, Casperson P, Harris CL, Chaitman BR, Shaw L, Gosselin G, Nawaz S, Title LM, Gau G, Blaustein AS, Booth DC, Bates ER, Spertus JA, Berman DS, Mancini GBJ, Weintraub WS. **Optimal medical therapy with or without PCI for stable coronary disease.** *New Eng J Med* 2007;356:1503–1516.	2376	238
12	**Use of a monoclonal antibody directed against the platelet glycoprotein IIb/IIIa receptor in high-risk coronary angioplasty.** *New Eng J Med* 1994;330:956–961.	2357	102
13	Stone GW, Ellis SG, Cox DA, Hermiller J, O'Shaughnessy C, Mann JT, Turco M, Caputo R, Bergin P, Greenberg J, Popma JJ, Russell ME. **A Polymer-Based, Paclitaxel-Eluting Stent in Patients with Coronary Artery Disease.** *New Eng J Med* 2004;350:221–231.	2345	180
14	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 Eng J Med* 2011;364:2187–2198.	2217	370
15	Yadav JS, Wholey MH, Kuntz RE, Fayad P, Katzen BT, Mishkel GJ, Bajwa TK, Whitlow P, Strickman NE, Jaff MR, Popma JJ, Snead DB, Cutlip DE, Firth BG, Ouriel K. **Protected carotid-artery stenting versus endarterectomy in high-risk patients.** *New Eng J Med* 2004;351:1493–1501 + 1586.	2035	157
16	Serruvs PW, Morice MC, Kappetein AP, Colombo A, Holmes DR, Mack MJ, Ståhle E, Feldman TE, Van Den Brand M, Bass EJ, Van Dyck N, Leadley K, Dawkins KD, Mohr FW. **Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease.** *New Eng J Med* 2009;360:961–972.	2022	253
17	Ommen SR, Nishimura RA, Appleton CP, Miller FA, Oh JK, Redfield MM, Tajik AJ. **Clinical utility of Doppler echocardiography and tissue Doppler imaging in the estimation of left ventricular filling pressures: A comparative simultaneous Doppler-catheterization study.** *Circulation* 2000;102:1788–1794.	1894	111
18	Joner M, Finn AV, Farb A, Mont EK, Kolodgie FD, Ladich E, Kutys R, Skorija K, Gold HK, Virmani R. **Pathology of Drug-Eluting Stents in Humans. Delayed Healing and Late Thrombotic Risk.** *J Am Coll Cardiol* 2006;48:193–202.	1875	170
19	Michael Lincoff A. **Platelet glycoprotein IIb/IIIa receptor blockade and low-dose heparin during percutaneous coronary revascularization.** *New Eng J Med* 1997;336:1689–1696.	1780	89

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Rank	Article	Citations	Citations per year
20	Wollert KC, Meyer GP, Lotz J, Ringes-Lichtenberg S, Lippolt P, Breidenbach C, Fichtner S, Korte T, Hornig B, Messinger D, Arseniev L, Hertenstein B, Ganser A, Drexler H. **Intracoronary autologous bone-marrow cell transfer after myocardial infarction: The BOOST randomised controlled clinical trial.** *Lancet* 2004;364:141–148.	1725	133
21	Strauer BE, Brehm M, Zeus T, Köstering M, Hernandez A, Sorg RV, Kögler G, Wernet P. **Repair of infarcted myocardium by autologous intracoronary mononuclear bone marrow cell transplantation in humans.** *Circulation* 2002;106:1913–1918.	1724	115
22	Grines CL, Browne KF, Marco J, Rothbaum D, Stone GW, O'Keefe J, Overlie P, Donohue B, Chelliah N, Timmis GC, Vlietstra RE, Strzelecki M, Puchrowicz-Ochocki S, O'Neill WW. **A Comparison of Immediate Angioplasty with Thrombolytic Therapy for Acute Myocardial Infarction.** *New Eng J Med* 1993;328:673–679.	1685	70
23	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;106:3006–3008.	1642	109
24	Schömig A, Neumann FJ, Kastrati A, Schühlen H, Blasini R, Hadamitzky M, Walter H, Zitzmann-Roth EM, Richardt G, Alt E, Schmitt C, Ulm K. **A randomized comparison of antiplatelet and anticoagulant therapy after the placement of coronary-artery stents.** *New Eng J Med* 1996;334:1084–1089.	1610	77
25	Connors Jr AF, Speroff T, Dawson NV, Thomas C, Harrell Jr FE, Wagner D, Desbiens N, Goldman L, Wu AW, Califf RM, Fulkerson Jr WJ, Vidaillet H, Broste S, Bellamy P, Lynn J, Knaus WA. **The effectiveness of right heart catheterization in the initial care of critically ill patients.** *JAMA* 1996;276:889–897.	1575	75
26	Tonino PAL, De Bruyne B, Pijls NHJ, Siebert U, Ikeno F, Van't Veer M, Klauss V, Manoharan G, Engstrøm T, Oldroyd KG, Ver Lee PN, MacCarthy PA, Fearon WF. **Fractional flow reserve versus angiography for guiding percutaneous coronary intervention.** *New Eng J Med* 2009;360:213–224.	1516	190
27	Grüntzig AR, Senning Å, Siegenthaler WE. **Nonoperative Dilatation of Coronary-Artery Stenosis: Percutaneous Transluminal Coronary Angioplasty.** *New Eng J Med* 1979;301:61–68.	1468	39
28	Seldinger SI. **Catheter replacement of the needle in percutaneous arteriography: A new technique.** *Acta Radiol* 1953;39:368–376.	1388	22
29	Brott TG, Hobson Ii RW, Howard G, Roubin GS, Clark WM, Brooks W, Mackey A, Hill MD, Leimgruber PP, Sheffet AJ, Howard VJ, Moore WS, Voeks JH, Hopkins LN, Cutlip DE, Cohen DJ, Popma JJ, Ferguson RD, Cohen SN, Blackshear JL, Silver FL, Mohr JP, Lal BK, Meschia JF. **Stenting versus endarterectomy for treatment of carotid-artery stenosis.** *New Eng J Med* 2010;363:11–23.	1378	197
30	Topol EJ. **Randomised placebo-controlled and balloon-angioplasty-controlled trial to assess safety of coronary stenting with use of platelet glycoprotein-IIb/IIIa blockade.** *Lancet* 1998;352:87–92.	1368	72
31	Leon MB, Baim DS, Popma JJ, Gordon PC, Cutlip DE, Ho KKL, Giambartolomei A, Diver DJ, Lasorda DM, Williams DO, Pocock SJ, Kuntz RE. **A clinical trial comparing three antithrombotic-drug regimens after coronary-artery stenting.** *New Eng J Med* 1998;339:1665–1671.	1350	71
32	Frye RL, Alderman EL, Andrews K, Bost J, Bourassa M, Chaitman BR, Detre K, Faxon DP, Follmann D, Hlatky M, Jones RH, Kelsey SF, Rogers WJ, Rosen AD, Schaff H, Sellers MA, Sopko G, Tyrrell KS, Williams DO. **Comparison of coronary bypass surgery with angioplasty in patients with multivessel disease: The Bypass Angioplasty Revascularization Investigation (BARI) investigators.** *New Eng J Med* 1996;335:217–225.	1328	63
33	Stone GW, Moses JW, Ellis SG, Schofer J, Dawkins KD, Morice MC, Colombo A, Schampaert E, Grub E, Kirtane AJ, Cutlip DE, Fahy M, Pocock SJ, Mehran R, Leon MB. **Safety and efficacy of sirolimus- and paclitaxel-eluting coronary stents.** *New Eng J Med* 2007;356:998–1008.	1319	132
34	Simoons ML. **Randomised placebo-controlled trial of abciximab before and during coronary intervention in refractory unstable angina: The CAPTURE study.** *Lancet* 1997;349:1429–1435.	1312	66
35	Daemen J, Wenaweser P, Tsuchida K, Abrecht L, Vaina S, Morger C, Kukreja N, Jüni P, Sianos G, Hellige G, van Domburg RT, Hess OM, Boersma E, Meier B, Windecker S, Serruys PW. **Early and late coronary stent thrombosis of sirolimus-eluting and paclitaxel-eluting stents in routine clinical practice: data from a large two-institutional cohort study.** *Lancet* 2007;369:667–678.	1307	131
36	Wilkoff BL, Cook JR, Epstein AE, Greene L, Hallstrom AP, Hsia H, Kutalek SP, Sharma A, Blatt B, Karas B, Kirchhoffer J, Warwick D, Duquette M, Provencher J, Redmond M, Herre JM, Bernstein R, Klevan LR, Barackman KD, Zumbuhl J, Chung MK, Jaeger FJ, Martin D, Natale A, Saliba WI, Schweikert RA, Niebauer MJ, Joseph Tchou P, Rozich R, Roelke M, Costeas CA, Rubenstein DG, Ruffo S, Kumar K, McCarthy E, Pastore V, Wathen MS, Rottman J, Anderson M, Lee JT, Murray KT, Roden DM, Conners N, Saunders S, O'Neill GP, Skadsen A, Allen S, Vierra E, Greer S, Neuhauser J, Myers P, Lee C, Moore T, Klein RC, Freedman RA, Wadsworth G, Dailey SM, Neal Kay G, Plumb VJ, Bubien RS, Kay LW, Nasser CM, Slabaugh JE, Leman R, Lake JL, Clark J, Clarke E, Finklea L, Love JC, Carpenter CM, Corsello A, Cutler JE, BosworthFarrell S, Michaud G, Buxton AE, Ellison KE, Christian F, Kirk MM, Corcoran PL, Rothbart S, Sauberman RB, McCarthy J, Page ME, Steinberg JS, Ehlert F, Herweg B, Vloka M, Malinay A, Menchavez E, Rome M, Marks K, Swarens A, Hernandez M, Marinchak R, Esberg D, Finkle J, Harper G, Kowey PR, Movsowitz C. **Dual-chamber pacing or ventricular backup pacing in patients with an implantable defibrillator: The Dual Chamber and VVI Implantable Defibrillator (DAVID) Trial.** *JAMA* 2002;288:3115–3123.	1300	87
37	Yamanaka O, Hobbs RE. **Coronary artery anomalies in 126,595 patients undergoing coronary arteriography.** *Cathet Cardiovasc Diagn* 1990;21:28–40.	1246	46

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Rank	Article	Citations	Citations per year
38	Stone GW, Witzenbichler B, Guagliumi G, Peruga JZ, Brodie BR, Dudek D, Kornowski R, Hartmann F, Gersh BJ, Pocock SJ, Dangas G, Wong SC, Kirtane AJ, Parise H, Mehran R. **Bivalirudin during primary PCI in acute myocardial infarction.** *New Eng J Med* 2008;358:2218–2230.	1236	137
39	Raff GL, Gallagher MJ, O'Neill WW, Goldstein JA. **Diagnostic accuracy of noninvasive coronary angiography using 64-slice spiral computed tomography.** *J Am Coll Cardiol* 2005;46:552–557.	1225	102
40	Colombo A, Hall P, Nakamura S, Almagor Y, Maiello L, Martini G, Gaglione A, Goldberg SL, Tobis JM. **Intracoronary stenting without anticoagulation accomplished with intravascular ultrasound guidance.** *Circulation* 1995;91:1676–1688.	1219	55
41	Sigwart U, Puel J, Mirkovitch V, Joffre F, Kappenberger L. **Intravascular Stents to Prevent Occlusion and Re-Stenosis after Transluminal Angioplasty.** *New Eng J Med* 1987;316:701–706.	1207	40
42	Gibson CM, Cannon CP, Daley WL, Dodge Jr JT, Alexander B, Marble SJ, McCabe CH, Raymond L, Fortin T, Poole WK, Braunwald E. **TIMI frame count: A quantitative method of assessing coronary artery flow.** *Circulation* 1996;93:879–888.	1186	56
43	Virmani R, Guagliumi G, Farb A, Musumeci G, Grieco N, Motta T, Mihalcsik L, Tespili M, Valsecchi O, Kolodgie FD. **Localized Hypersensitivity and Late Coronary Thrombosis Secondary to a Sirolimus-Eluting Stent: Should We Be Cautious?** *Circulation* 2004;109:701–705.	1182	91
44	McFadden EP, Stabile E, Regar E, Cheneau E, Ong ATL, Kinnaird T, Suddath WO, Weissman NJ, Torguson R, Kent KM, Pichard AD, Satler LF, Waksman R, Serruys PW. **Late thrombosis in drug-eluting coronary stents after discontinuation of antiplatelet therapy.** *Lancet* 2004;364:1519–1521.	1170	90
45	Schulman KA, Berlin JA, Harless W, Kerner JF, Sistrunk S, Gersh BJ, Dubé R, Taleghani CK, Burke JE, Williams S, Eisenberg JM, Escarce JJ, Ayers W. **The effect of race and sex on physicians' recommendations for cardiac catheterization.** *New Eng J Med* 1999;340:618–626.	1153	64
46	Brown MM. **Endovascular versus surgical treatment in patients with carotid stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS): A randomised trial.** *Lancet* 2001;357:1729–1737.	1141	71
47	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 Eng J Med* 2012;366:1686–1695.	1129	226
48	Pijls NHJ, De Bruyne B, Peels K, Van Der Voort PH, Bonnier HJRM, Bartunek J, Koolen JJ. **Measurement of fractional flow reserve to assess the functional severity of coronary-artery stenoses.** *New Eng J Med* 1996;334:1703–1708.	1129	54
49	Pfisterer M, Brunner-La Rocca HP, Buser PT, Rickenbacher P, Hunziker P, Mueller C, Jeger R, Bader F, Osswald S, Kaiser C. **Late Clinical Events After Clopidogrel Discontinuation May Limit the Benefit of Drug-Eluting Stents. An Observational Study of Drug-Eluting Versus Bare-Metal Stents.** *J Am Coll Cardiol* 2006;48:2584–2591.	1128	103
50	Mas JL, Chatellier G, Beyssen B, Branchereau A, Moulin T, Becquemin JP, Larrue V, Lièvre M, Leys D, Bonneville JF, Watelet J, Pruvo JP, Albucher JF, Viguier A, Piquet P, Garnier P, Viader F, Touzé E, Giroud M, Hosseini H, Pillet JC, Favrole P, Neau JP, Ducrocq X. **Endarterectomy versus stenting in patients with symptomatic severe carotid stenosis.** *New Eng J Med* 2006;355:1660–1671.	1126	102
51	Mauri L, Hsieh WH, Massaro JM, Ho KKL, D'Agostino R, Cutlip DE. **Stent thrombosis in randomized clinical trials of drug-eluting stents.** *New Eng J Med* 2007;356:1020–1029.	1121	112
52	Pappone C, Rosanio S, Oreto G, Tocchi M, Gugliotta F, Vicedomini G, Salvati A, Dicandia C, Mazzone P, Santinelli V, Gulletta S, Chierchia S. **Circumferential radiofrequency ablation of pulmonary vein ostia: A new anatomic approach for curing atrial fibrillation.** *Circulation* 2000;102:2619–2628.	1090	64
53	Hoffmann R, Mintz GS, Dussaillant GR, Popma JJ, Pichard AD, Satler LF, Kent KM, Griffin J, Leon MB. **Patterns and mechanisms of in-stent restenosis: A serial intravascular ultrasound study.** *Circulation* 1996;94:1247–1254.	1086	52
54	Dake MD, Semba CP, Liddell RP, Miller DC, Mitchell RS, Walker PJ. **Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms.** *New Eng J Med* 1994;331:1729–1734.	1084	47
55	Rentrop KP, Cohen M, Blanke H, Phillips RA. **Changes in collateral channel filling immediately after controlled coronary artery occlusion by an angioplasty balloon in human subjects.** *J Am Coll Cardiol* 1985;5:587–592.	1084	34
56	Swan HJC, Ganz W, Forrester J, Marcus H, Diamond G, Chonette D. **Catheterization of the Heart in Man with Use of a Flow-Directed Balloon-Tipped Catheter.** *New Eng J Med* 1970;283:447–451.	1083	23
57	Budoff MJ, Dowe D, Jollis JG, Gitter M, Sutherland J, Halamert E, Scherer M, Bellinger R, Martin A, Benton R, Delago A, Min JK. **Diagnostic Performance of 64-Multidetector Row Coronary Computed Tomographic Angiography for Evaluation of Coronary Artery Stenosis in Individuals Without Known Coronary Artery Disease. Results From the Prospective Multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) Trial.** *J Am Coll Cardiol* 2008;52:1724–1732.	1081	120
58	Mehran R, Aymong ED, Nikolsky E, Lasic Z, Iakovou I, Fahy M, Mintz GS, Lansky AJ, Moses JW, Stone GW, Leon MB, Dangas G. **A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: Development and initial validation.** *J Am Coll Cardiol* 2004;44:1393–1399.	1061	82
59	Zijlstra F, de Boer MJ, Hoorntje J, Reiffers S, Reiber J, Suryapranata H. **A Comparison of Immediate Coronary Angioplasty with Intravenous Streptokinase in Acute Myocardial Infarction.** *New Eng J Med* 1993;328:680–684.	1055	44

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Rank	Article	Citations	Citations per year
60	Stone GW, Grines CL, Cox DA, Garcia E, Tcheng JE, Griffin JJ, Guagliumi G, Stuckey T, Turco M, Carroll JD, Rutherford BD, Lansky AJ. **Comparison of angioplasty with stenting, with or without abciximab, in acute myocardial infarction.** *New Eng J Med* 2002;346:957–966.	1052	70
61	Ringleb PA, Allenberg J, Brückmann H, Eckstein HH, Fraedrich G, Hartmann M, Hennerici M, Jansen O, Klein G, Kunze A, Marx P, Niederkorn K, Schmiedt W, Solymosi L, Stingele R, Zeumer H, Hacke W**. 30 day results from the SPACE trial of stent-protected angioplasty versus carotid endarterectomy in symptomatic patients: a randomised non-inferiority trial.** *Lancet* 2006;368:1239–1247.	1047	95
62	Rihal CS, Textor SC, Grill DE, Berger PB, Ting HH, Best PJ, Singh M, Bell MR, Barsness GW, Mathew V, Garratt KN, Holmes Jr DR. **Incidence and prognostic importance of acute renal failure after percutaneous coronary intervention.** *Circulation* 2002;105:2259–2264.	1038	69
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64	Montalescot G, Barragan P, Wittenberg O, Ecollan P, Elhadad S, Villain P, Boulenc JM, Morice MC, Maillard L, Pansiéri M, Choussat R, Pinton P. **Platelet glycoprotein IIb/IIIa inhibition with coronary stenting for acute myocardial infarction.** *New Eng J Med* 2001;344:1895–1903.	1034	65
65	Miller JM, Rochitte CE, Dewey M, Arbab-Zadeh A, Niinuma H, Gottlieb I, Paul N, Clouse ME, Shapiro EP, Hoe J, Lardo AC, Bush DE, De Roos A, Cox C, Brinker J, Lima JAC. **Diagnostic performance of coronary angiography by 64-row CT.** *New Eng J Med* 2008;359:2324–2336.	1028	114
66	Leber AW, Knez A, Von Ziegler F, Becker A, Nikolaou K, Paul S, Wintersperger B, Reiser M, Becker CR, Steinbeck G, Boekstegers P. **Quantification of obstructive and nonobstructive coronary lesions by 64-slice computed tomography: A comparative study with quantitative coronary angiography and intravascular ultrasound.** *J Am Coll Cardiol* 2005;46:147–154.	1023	85
67	Hertzer NR, Beven EG, Young JR, O'Hara PJ, Ruschhaupt Iii WF, Graor RA, Dewolfe VG, Maljovec LC. **Coronary artery disease in peripheral vascular patients. A classification of 1000 coronary angiograms and results of surgical management.** *Ann Surg* 1984;199:223–233.	1022	31
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69	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;82:1193–1202.	1014	38
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72	Lunde K, Solheim S, Aakhus S, Arnesen H, Abdelnoor M, Egeland T, Endresen K, Ilebekk A, Mangschau A, Fjeld JG, Smith HJ, Taraldsrud E, Grøgaard HK, Bjørnerheim R, Brekke M, Müller C, Hopp E, Ragnarsson A, Brinchmann JE, Forfang K. **Intracoronary injection of mononuclear bone marrow cells in acute myocardial infarction.** *New Eng J Med* 2006;355:1199–1209.	978	89
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75	Sandham JD, Hull RD, Frederick Brant R, Knox L, Pineo GF, Doig CJ, Laporta DP, Viner S, Passerini L, Devitt H, Kirby A, Jacka M. **A randomized, controlled trial of the use of pulmonary-artery catheters in high-risk surgical patients.** *New Eng J Med* 2003;348:5–14.	928	66
76	Mehran R, Dangas G, Abizaid AS, Mintz GS, Lansky AJ, Satler LF, Pichard AD, Kent KM, Stone GW, Leon MB. **Angiographic patterns of in-stent restenosis: Classification and implications for long-term outcome.** *Circulation* 1999;100:1872–1878.	911	51
77	Colombo A, Drzewiecki J, Banning A, Grube E, Hauptmann K, Silber S, Dudek D, Fort S, Schiele F, Zmudka K, Guagliumi G, Russell ME. **Randomized study to assess the effectiveness of slow- and moderate-release polymer-based paclitaxel-eluting stents for coronary artery lesions.** *Circulation* 2003;108:788–794.	902	64
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Rank	Article	Citations	Citations per year
79	Dake MD, Kato N, Mitchell RS, Semba CP, Razavi MK, Shimono T, Hirano T, Takeda K, Yada I, Miller DC. **Endovascular stent-graft placement for the treatment of acute aortic dissection.** *New Eng J Med* 1999;340:1546–1552.	888	49
80	Serruys PW, Unger F, Sousa JE, Jatene A, Bonnier HJRM, Schönberger JPAM, Buller N, Bonser R, Van Den Brand MJB, Van Herwerden LA, Morel MAM, Van Hout BA. **Comparison of coronary-artery bypass surgery and stenting for the treatment of multivessel disease.** *New Eng J Med* 2001;344:1117–1124.	887	55
81	Nieman K, Cademartiri F, Lemos PA, Raaijmakers R, Pattynama PMT, De Feyter PJ. **Reliable noninvasive coronary angiography with fast submillimeter multislice spiral computed tomography.** *Circulation* 2002;106:2051–2054.	886	59
82	Mollet NR, Cademartiri F, Van Mieghem CAG, Runza G, McFadden EP, Baks T, Serruys PW, Krestin GP, De Feyter PJ. **High-resolution spiral computed tomography coronary angiography in patients referred for diagnostic conventional coronary angiography.** *Circulation* 2005;112:2318–2323.	882	74
83	King Iii SB. **Effects of platelet glycoprotein IIb/IIIa blockade with tirofiban on adverse cardiac events in patients with unstable angina or acute myocardial infarction undergoing coronary angioplasty.** *Circulation* 1997;96:1445–1453.	877	44
84	Schofer J, Schlüter M, Gershlick AH, Wijns W, Garcia E, Schampaert E, Breithardt G. **Sirolimus-eluting stents for treatment of patients with long atherosclerotic lesions in small coronary arteries: Double-blind, randomised controlled trial (E-SIRIUS).** *Lancet* 2003;362:1093–1099.	876	63
85	Smith WS, Sung G, Saver J, Budzik R, Duckwiler G, Liebeskind DS, Lutsep HL, Rymer MM, Higashida RT, Starkman S, Gobin YP. **Mechanical thrombectomy for acute ischemic stroke: Final results of the multi MERCI trial.** *Stroke* 2008;39:1205–1212.	872	97
86	Jaïs P, Haïssaguerre M, Shah DC, Chouairi S, Gencel L, Hocini M, Clémenty J. **A focal source of atrial fibrillation treated by discrete radiofrequency ablation.** *Circulation* 1997;95:572–576.	871	44
87	Finn AV, Joner M, Nakazawa G, Kolodgie F, Newell J, John MC, Gold HK, Virmani R. **Pathological correlates of late drug-eluting stent thrombosis: Strut coverage as a marker of endothelialization.** *Circulation* 2007;115:2435–2441.	866	87
88	Teirstein PS, Massullo V, Jani S, Popma JJ, Mintz GS, Russo RJ, Schatz RA, Guarneri EM, Steuterman S, Morris NB, Leon MB, Tripuraneni P. **Catheter-based radiotherapy to inhibit restenosis after coronary stenting.** *New Eng J Med* 1997;336:1697–1703.	866	43
89	Leschka S, Alkadhi H, Plass A, Desbiolles L, Grünenfelder J, Marincek B, Wildermuth S. **Accuracy of MSCT coronary angiography with 64-slice technology: First experience.** *Eur Heart J* 2005;26:1482–1487.	864	72
90	Ropers D, Baum U, Pohle K, Anders K, Ulzheimer S, Ohnesorge B, Schlundt C, Bautz W, Daniel WG, Achenbach S. **Detection of coronary artery stenoses with thin-slice multi-detector row spiral computed tomography and multiplanar reconstruction.** *Circulation* 2003;107:664–666.	861	62
91	Ellis SG. **A clinical trial comparing primary coronary angioplasty with tissue plasminogen activator for acute myocardial infarction.** *New Eng J Med* 1997;336:1621–1628.	845	42
92	Shaw LJ, Berman DS, Maron DJ, Mancini GBJ, Hayes SW, Hartigan PM, Weintraub WS, O'Rourke RA, Dada M, Spertus JA, Chaitman BR, Friedman J, Slomka P, Heller GV, Germano G, Gosselin G, Berger P, Kostuk WJ, Schwartz RG, Knudtson M, Veledar E, Bates ER, McCallister B, Teo KK, Boden WE. **Optimal medical therapy with or without percutaneous coronary intervention to reduce ischemic burden: results from the Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) trial nuclear substudy.** *Circulation* 2008;117:1283–1291.	844	94
93	Cannon CP, Gibson CM, Lambrew CT, Shoultz DA, Levy D, French WJ, Gore JM, Weaver WD, Rogers WJ, Tiefenbrunn AJ. **Relationship of symptom-onset-to-balloon time and door-to-balloon time with mortality in patients undergoing angioplasty for acute myocardial infarction.** *Journal of the American Medical Association* 2000;283:2941–2947.	842	50
94	Holmes DR, Reddy VY, Turi ZG, Doshi SK, Sievert H, Buchbinder M, Mullin CM, Sick P. **Percutaneous closure of the left atrial appendage versus warfarin therapy for prevention of stroke in patients with atrial fibrillation: a randomised non-inferiority trial.** *The Lancet* 2009;374:534–542.	832	104
95	Nair A, Kuban BD, Tuzcu EM, Schoenhagen P, Nissen SE, Vince DG. **Coronary plaque classification with intravascular ultrasound radiofrequency data analysis.** *Circulation* 2002;106:2200–2206.	826	55
96	Jackman WM, Beckman KJ, McClelland JH, Wang X, Friday KJ, Roman CA, Moulton KP, Twidale N, Hazlitt HA, Prior MI, Oren J, Overholt ED, Lazzara R. **Treatment of Supraventricular Tachycardia Due to Atrioventricular Nodal Reentry by Radiofrequency Catheter Ablation of Slow-Pathway Conduction.** *New Eng J Med* 1992;327:313–318	825	33
97	De Luca G, Suryapranata H, Ottervanger JP, Antman EM. **Time Delay to Treatment and Mortality in Primary Angioplasty for Acute Myocardial Infarction: Every Minute of Delay Counts.** *Circulation* 2004;109:1223–1225.	821	63
98	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;87:394–402.	819	25
99	Grines CL, Cox DA, Stone GW, Garcia E, Mattos LA, Giambartolomei A, Brodie BR, Madonna O, Eijgelshoven M, Lansky AJ, O'Neill WW, Morice MC. **Coronary angioplasty with or without stent implantation for acute myocardial infarction.** *New Eng J Med* 1999;341:1949–1956.	817	45
100	Holmes Jr DR, Vlietstra RE, Smith HC, Vetrovec GW, Kent KM, Cowley MJ, Faxon DP, Gruentzig AR, Kelsey SF, Detre KM, Van Raden MJ, Mock MB. **Restenosis after percutaneous transluminal coronary angioplasty (PTCA): A report from the PTCA registry of the national heart, lung, and blood institute.** *Am J Cardiol* 1984;53:C77-C81.	815	25

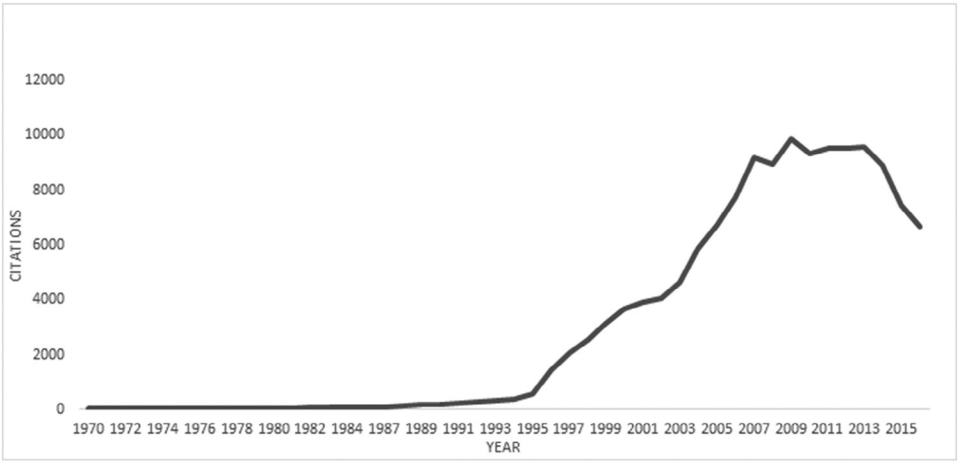

Figure 1. Variation of total citations of all articles with year.

Table 2
Authors with five or more articles in the top 100 list

Author	Publications in list	First position	Last position	Other positions	Affiliation	H-index
Martin B. León	13	2	5	6	Columbia University Medical Center, New York, United States	137
Greggory W. Stone	9	4	0	5	Columbia University Medical Center, New York, United States	115
Antonio Colombo	8	2	1	5	Fondazione San Raffaele del Monte Tabor, San Raffaele Scientific Institute, Milan, Italy	116
Jeffrey J. Popma	7	0	0	7	Beth Israel Deaconess Medical Center, Departments of Internal Medicine, Boston, United States	105
Jeffrey W. Moses	6	1	0	5	Cardiovascular Research Foundation, New York, United States	84
Marie C. Morice	6	1	1	4	ICPS Institut CardioVasculaire Paris-Sud, Massy, France	67
Patrick W Serruys	6	2	2	2	Imperial College London, International Centre for Circulatory Health, London, United Kingdom	136
Augusto D. Pichard	6	0	0	6	Washington Hospital Center, Section of Cardiology, Washington, United States	83
Donald E. Cutlip	5	0	1	4	Beth Israel Deaconess Medical Center, Department of Medicine, Boston, United States	65
Giulio Guagliumi	5	0	0	5	Azienda Ospedaliera Papa Giovanni XXIII, Interventional Cardiology Unit, Bergamo, Italy	56
David R. Holmes	5	1	2	2	Mayo Clinic, Rochester, United States	135
Stuart J. Pocock	5	0	2	3	London School of Hygiene & Tropical Medicine, Department of Medical Statistics, London, United Kingdom	108
Stephen G. Ellis	5	2	0	3	Cleveland Clinic Foundation, Department of Cardiovascular Medicine, Cleveland, United States	150

It must be noted that total citations give a good estimate of the impact an article has had in the scientific world since its publication; however, it gives no indication of its current influence. For this reason, the citations-per-year variable was added to Table 1. Articles with a high citation count and low citations-per-year have been landmark articles in the distant past. However, articles with high values in both continue to be important for researchers. Articles are listed according to number of citations per year in the Supplementary Table S1.

Coronary angioplasty and stenting have been particular areas of interest when compared with other areas within interventional cardiology. This is not surprising considering the high clinical incidence of myocardial infarction and the eternal challenge to minimize muscle damage during an episode of myocardial infarction. This interest has seen researchers test several variations of angioplasty by tweaking the time to treatment, the adjunctive pharmacologic therapy, and the type of stent. However, the incidence of valvular heart disease is steadily increasing and valvular heart diseases are expected to be the next epidemic in cardiology.[18] This is likely to result in increased research attention being given to transcatheter valve repair/replacement in the coming years. The fact that the article with the highest citations-per-year in the entire field of interventional cardiology studied minimally invasive valve repair is an indication that the focus of researchers is already shifting. Although only 4 articles focusing on percutaneous valve repair made it to our top 100 list, future bibliometrics might identify more landmark articles in this area.

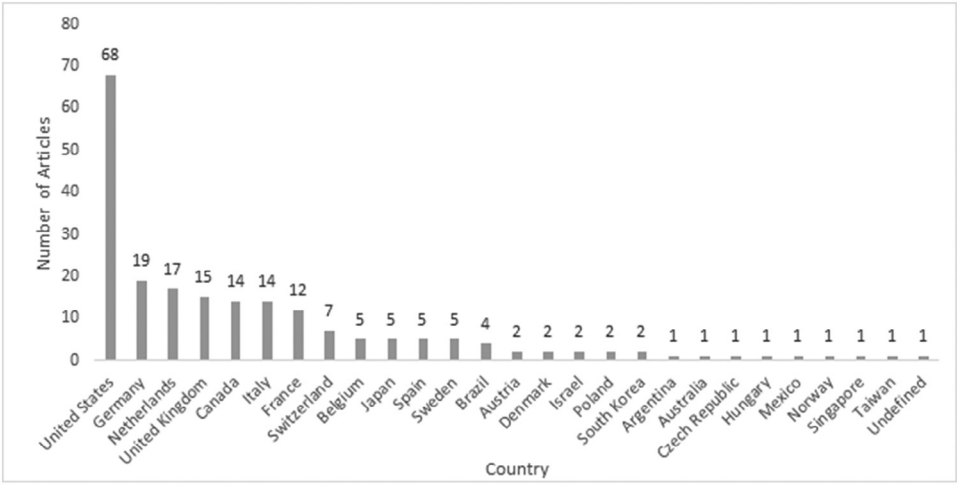

Figure 2. Number of articles originating from each country.

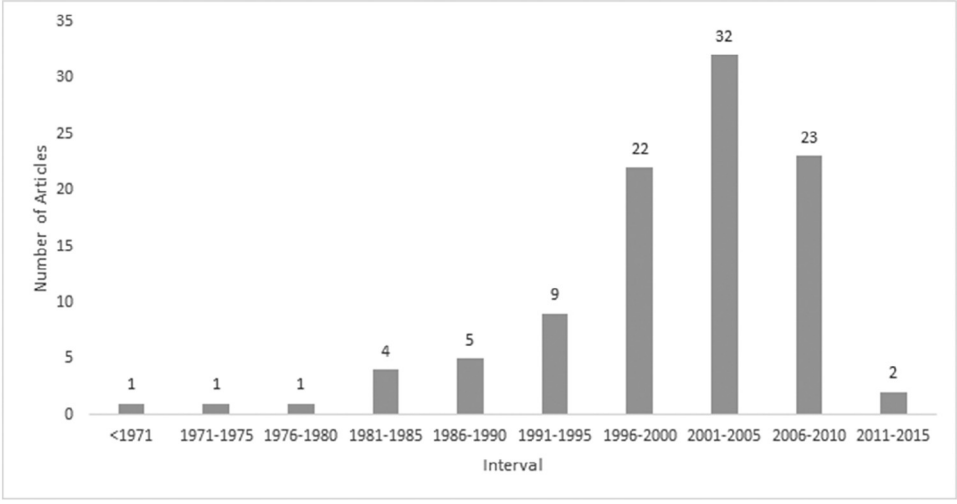

Figure 3. Articles originating in each 5-year interval.

Table 3
Journals with the most articles in the top 100 list

Journal	Number of Articles	2015 Impact Factor
New England Journal of Medicine	44	59.56
Circulation	22	17.20
Lancet	12	44.00
Journal of The American College of Cardiology	10	17.76
Journal of The American Medical Association	5	37.68

Majority (n = 78) of the articles in our list were published between 1996 and 2010. One would expect recent articles to have fewer citations as previously observed[11,19,20]; however, this trend is not detected in this analysis. In fact, over half (n = 58) of the articles in our top 100 list were published after the year 2000—similar trends have been noted in other bibliometrics performed in cardiology[8,12,21,22]—showing that research in interventional cardiology is developing in sync with the rest of cardiology. This portrays the dynamic nature of cardiology where constant improvements are being made and new guidelines are developed frequently. We found a significant positive correlation between the impact factor of a journal and the number of articles of that journal in the top 100 list. This reinforces the concept that the prestige of a journal plays a vital role in determining the impact its articles will have.

When viewing the contribution of various countries, it was noted that the United States was clearly the most prolific. European countries like Germany and The Netherlands came in at a distant second. A similar observation was made in previous bibliometric studies in both cardiology[21] and other fields[23] alike. The United States has an intricate infrastructure with a rewarding system in place for academia which leads to such an immense contribution. Similar to other bibliometrics on noncommunicable diseases,[24,25] we see a stark underrepresentation of Asian and South American countries with each contributing 10 and 6 papers, respectively. In contrast, bibliometrics on communicable diseases

show much greater, and more impactful, research output by low- and middle-income countries.[26,27] This discrepancy might be due to private funding agencies such as *Bill & Melinda Gates Foundation* and *Grand Challenges Canada* focusing their resources on infectious disease research and treatment in low- and middle-income countries. Noncommunicable diseases such as cardiovascular diseases remain a burden in these countries and deserve increased research attention. Furthermore, only 26% of the studies had authors from multiple countries. Collaboration between countries with established research programs and those developing can help create databases with worldwide contributions.

Our results should be viewed with some limitations. Firstly, Scopus tends to miss articles that were published before a computerized system was in place since the 1980s.[28] Secondly, self-citation can be a potential bias in bibliometrics; however, in these 100 articles, the self-citation rate was 5.97%, which is lower than the rate reported in general medicine articles (6.5%).[29] Furthermore, on removing self-citations there was no change in the rank of articles. And lastly, very recent articles which have the potential to become landmark articles may have been missed as it takes some time for articles to accumulate citations.

Disclosures

Dr. Khosa is the recipient of the Canadian Association of Radiologists/Canadian Radiological Foundation Leadership Scholarship (2017). The authors have no relevant disclosures, and they report no relations that could be construed as a conflict of interest. There was no commercial funding for this study. All authors have read and approved the final draft.

Supplementary Data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.amjcard.2017.08.030.

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