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# The 100 most cited articles in the endovascular treatment of thoracic and abdominal aortic aneurysms



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## ABSTRACT

**Objective:** Since the introduction of endovascular technology to treat thoracic and abdominal aortic aneurysms, there has been a global research effort focused on assessing the effectiveness of treatment. A bibliometric analysis is used to identify the scientific impact of an article, impactful authors, institutions, and collaborative groups. Our objective was to identify and to analyze the 100 most cited articles in the field of endovascular treatment of thoracic and abdominal aortic aneurysms.

**Methods:** We performed a retrospective bibliometric analysis in April 2018. Articles were searched on the Science Citation Index Expanded database using Web of Science to identify the most cited articles in endovascular therapy for thoracic and aortic aneurysms since 1945. Use of selected key terms ("AAA," "aortic aneurysm," "thoracic aneurysm," "abdominal aneurysm," "endovascular," "endoluminal," "stent," "graft," "repair," "EVAR," and "TEVAR") yielded a total of 23,354 articles. The top 100 articles were identified and analyzed to extract relevant information including year of publication, citation count, journal, authorship country of origin, and article type.

**Results:** The earliest articles were published in 1991, with the majority being published in the 2000s (n = 59). The number of citations for the top 100 articles ranged from 151 to 1142, with a median citation count of 212. All articles were cited an average of 22.4 times per year. Almost half (n = 46) of the top 100 articles were published in the *Journal of Vascular Surgery*. Thirty-nine authors contributed four or more articles, with two being credited on 10 papers to make the list. The majority (n = 62) of the articles arose from the United States, while the United Kingdom contributed 11 articles. There were 7 guidelines and 12 randomized controlled trials, and the majority constituted level III or level IV evidence.

**Conclusions:** This study provides a comprehensive and informative analysis of the most cited and impactful research undertaken in the field of endovascular treatment of abdominal and thoracic aortic aneurysms. By quantitatively assessing the 100 most cited articles in the field, we recognize the contributions of key authors, institutions, and collaborative groups and develop an understanding of the strengths of past research and the requirements for future global efforts. (J Vasc Surg 2018;68:1566-81.)

**Keywords:** Thoracic aortic aneurysm; Abdominal aortic aneurysm; EVAR; TEVAR; Endovascular; Citation analysis

Aneurysms of the aorta affect up to 8% of individuals aged >65 years, with progressive growth and subsequent rupture resulting in a mortality rate exceeding 50%.[1] In decades past, the only definitive treatment was open surgical repair of the aneurysm. This major operation is relatively safe when it is performed electively but carries a substantial risk of morbidity and mortality in the emergent setting.[2] In the late 1980s and early 1990s, the revolutionary work of Juan Carlos Parodi at the Instituto de Cardiovascular de Buenos Aires in Argentina and Nicolai Leontyevich Volodos at the Kharkov Research Institute of General and Urgent Surgery laid the groundwork for an alternative and less invasive treatment method now known as endovascular aneurysm repair (EVAR) and thoracic endovascular aortic repair (TEVAR).[3,4]

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The two decades following those initial experiments saw an international outpouring of both technologic development and clinical research into producing and refining better commercial stent graft designs, with each new generation of devices addressing limitations and pitfalls, such as endograft migration, graft porosity, and endoleaks, based on increasing exposure with EVAR. Multiple medical companies developed competing stent technologies,[5] and multicenter databases and trials,[6,7] such as the Dutch Randomized Endovascular Aneurysm Management (DREAM) and European Collaborators on Stent/graft Techniques for aortic Aneurysm Repair (EUROSTAR), began to assess the efficacy, safety, and cost-effectiveness of EVAR. This led to a large volume of prospective data, randomized controlled trials (RCTs), and retrospective analyses to shape EVAR's role alongside traditional open aneurysm repair.

A bibliometric analysis is a straightforward, standardized method of identifying the key articles and assessing trends, strengths, and gaps in the current literature available on a topic.[8] A citation analysis is the most common type of bibliometric analysis and focuses on the most highly cited articles, thus giving quantifiable insight into the most impactful papers, authors, institutions, and journals. Furthermore, because articles accrue citations with time and strength of evidence, a citation analysis also provides both a chronologic overview of the progression of research and a look at the most clinically relevant evidence for practitioners.[8]

To date, no bibliometric analysis specifically looking at endovascular treatment of aortic aneurysms has been performed. A citation analysis examining emergency abdominal surgery in general found that more than a quarter of the top 100 most cited manuscripts related to vascular disease, largely ruptured or leaking abdominal aortic aneurysms.[9] This highlights the importance of the topic and reinforces the volume of research in recent times. The aim of this citation analysis was to gain a detailed understanding of the most significant research in the field of EVAR and TEVAR by examining the year of publication, authorship, institution, country of origin, journal of publication, subject, citation count, and level of evidence.

## METHODS

**Literature search.** A retrospective search of the Web of Science (Thomson Reuters, New York, NY) database was conducted in April 2018. This platform searches the Science Citation Index Expanded database, allowing access to >12,000 peer-reviewed journals. The keywords used were "AAA," "aortic aneurysm," "thoracic aneurysm," "abdominal aneurysm," "endovascular," "endoluminal," "stent," "graft," "repair," "EVAR," and "TEVAR" combined with AND and OR Boolean operators. The search yielded 23,354 results that were subsequently ranked by the number of citations.

Analysis of individual articles for relevance to the topic at hand was then performed by the primary author (K.Z.Z.) based on title, abstract, and full text. Bibliographies were also parsed for any commonly cited or notable articles to ensure that they were captured in the initial literature search. Where there was ambiguity, input and arbitration were provided in consensus by two senior authors (J.M. and H.A.). Analysis was continued until consensus was achieved on the top 100 most cited articles; 167 articles were assessed as not being relevant to the topic. Once the top 100 list was compiled, each article was individually cross-checked with Google Scholar to ensure accuracy in the citation and information. A citation count from Google Scholar was also recorded as a comparator to the Web of Science database. This methodology was previously validated and used in other published bibliometric studies.[10]

**Analysis.** The articles were then analyzed for authorship, citation count, average citations per year, journal, institution, country, subject matter, date of publication, and level of evidence. When there was uncertainty, a decision was made with input from senior authors. The final results were tabulated and reviewed by all authors to ensure consensus.

## RESULTS

**Citations, trends, and date of publication.** The 100 most cited articles about endovascular treatment of aortic aneurysms are listed in Table I. The earliest papers to make the list are from 1991, when Parodi[3] and Volodos[4] reported the use of EVAR and TEVAR stent grafts in humans. However, Volodos[11] actually first reported on endovascular repair in a Russian article in 1988. It was not as heavily cited but note was taken regardless because of its tremendous historical significance. The majority of articles (n = 59) were published between 2000 and 2009, with the fewest (n = 11) being published since 2010. Based on the Web of Science count, the number of citations ranged from 151 to 1142, with a median of 212.

The most cited paper according to Web of Science is "A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms," published in the *New England Journal of Medicine* in 2004 and a product of the multicenter DREAM trial group.[6] It has 1142 citations and also has the fourth highest amount of citations per year (76.13).

The most frequently cited paper is the "2014 ESC Guidelines on the diagnosis and treatment of aortic diseases" with a citation per year count of 117.2 in Web of Science.[12] It is also notable for only being published in 2014, the most recent article in the top 100 list. The 10 most frequently cited articles, according to Web of Science, consist of 4 guidelines and 6 RCTs including 3 papers published from the EVAR trial. The average citations per year of those 10 articles is 70.7, whereas the average of all articles is 22.4.

**Table I.** The top 100 most cited articles on endovascular treatment of abdominal and thoracic aortic aneurysms

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 1 | Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg 1991;5:491-9.[a] | | | 3929 |
| 2 | Prinssen M, Verhoeven EL, Buth J, Cuypers PW, van Sambeek MR, Balm R, et al. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004;351:1607-18. | 1142 | 76.13 | 1761 |
| 3 | Greenhalgh RM. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet 2004;364:843-8. | 1105 | 73.67 | 1610 |
| 4 | Dake MD, Miller DC, Semba CP, Mitchell RS, Walker PJ, Liddell RP. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. N Engl J Med 1994;331:1729-34. | 1000 | 40 | 1802 |
| 5 | Chaikof EL, Blankensteijn JD, Harris PL, White GH, Zarins CK, Bernhard VM, et al. Reporting standards for endovascular aortic aneurysm repair. J Vasc Surg 2002;35:1048-60. | 847 | 49.82 | 1172 |
| 6 | EVAR trial participants. Endovascular aneurysm repair versus open repair in patients with abdominal aortic aneurysm (EVAR trial 1): randomised controlled trial. Lancet 2005;365:2179-86. | 772 | 55.14 | 600 |
| 7 | Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE, et al 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease. Circulation 2010;121:e266-369. | 766 | 85.11 | 1686 |
| 8 | United Kingdom EVAR Trial Investigators. Endovascular versus open repair of abdominal aortic aneurysm. N Engl J Med 2010;362:1863-71. | 702 | 78 | 1018 |
| 9 | Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic). Circulation 2006;113:e463-654. | 698 | 53.69 | 2314 |
| 10 | Blankensteijn JD, de Jong SE, Prinssen M, van der Ham AC, Buth J, van Sterkenburg SM, et al. Two-year outcomes after conventional or endovascular repair of abdominal aortic aneurysms. N Engl J Med 2005;352:2398-405. | 591 | 42.21 | 954 |
| 11 | Erbel R, Aboyans V, Boileau C, Bossone E, Bartolomeo RD, Eggebrecht H, et al. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). Eur Heart J 2014;35:2873-926. | 586 | 117.2 | 954 |
| 12 | Blum U, Voshage G, Lammer J, Beyersdorf F, Töllner D, Kretschmer G, et al. Endoluminal stent-grafts for infrarenal abdominal aortic aneurysms. N Engl J Med 1997;336:13-20. | 532 | 24.18 | 786 |
| 13 | Moll FL, Powell JT, Fraedrich G, Verzini F, Haulon S, Waltham M, et al. Management of abdominal aortic aneurysms clinical practice guidelines of the European Society for Vascular Surgery. Eur J Vasc Endovasc Surg 2011;41:S1-58. | 531 | 66.38 | 819 |
| 14 | White GH, Yu W, May J, Chaufour X, Stephen MS. Endoleak as a complication of endoluminal grafting of abdominal aortic aneurysms: classification, incidence, diagnosis, and management. J Endovasc Ther 1997;4:152-68. | 523 | 23.77 | 811 |
| 15 | Lederle FA, Freischlag JA, Kyriakides TC, Padberg FT, Matsumura JS, Kohler TR, et al. Outcomes following endovascular vs open repair of abdominal aortic aneurysm: a randomized trial. JAMA 2009;302:1535-42. | 498 | 49.8 | 728 |
| 16 | Harris PL, Vallabhaneni SR, Desgranges P, Becquemin JP, van Marrewijk C, Laheij RJ. Incidence and risk factors of late rupture, conversion, and death after endovascular repair of infrarenal aortic aneurysms: the EUROSTAR experience. J Vasc Surg 2000;32:739-49. | 473 | 24.89 | 687 |

**Table I.** Continued.

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 17 | De Bruin JL, Baas AF, Buth J, Prinssen M, Verhoeven EL, Cuypers PW, et al. Long-term outcome of open or endovascular repair of abdominal aortic aneurysm. N Engl J Med 2010;362:1881-9. | 471 | 52.33 | 745 |
| 18 | Svensson LG, Kouchoukos NT, Miller DC, Bavaria JE, Coselli JS, Curi MA, et al. Expert consensus document on the treatment of descending thoracic aortic disease using endovascular stent-grafts. Ann Thorac Surg 2008;85:S1-41. | 468 | 42.55 | 777 |
| 19 | Zarins CK, White RA, Schwarten D, Kinney E, Diethrich EB, Hodgson KJ, et al. AneuRx stent graft versus open surgical repair of abdominal aortic aneurysms: multicenter prospective clinical trial. J Vasc Surg 1999;29:292-308. | 466 | 23.3 | 666 |
| 20 | Schermerhorn ML, O'Malley AJ, Jhaveri A, Cotterill P, Pomposelli F, Landon BE. Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population. N Engl J Med 2008;358:464-74. | 438 | 39.82 | 716 |
| 21 | Parodi JC. Endovascular repair of abdominal aortic aneurysms and other arterial lesions. J Vasc Surg 1995;21:549-57. | 410 | 17.08 | 610 |
| 22 | Greenhalgh RM, Brown LC, Epstein D, Kwong G, Powell JT, Sculpher MJ. Endovascular aneurysm repair and outcome in patients unfit for open repair of abdominal aortic aneurysm (EVAR trial 2): randomised controlled trial. Lancet 2005;365:2187-92. | 407 | 29.07 | 601 |
| 23 | Makaroun MS, Dillavou ED, Kee ST, Sicard G, Chaikof E, Bavaria J, et al. Endovascular treatment of thoracic aortic aneurysms: results of the phase II multicenter trial of the GORE TAG thoracic endoprosthesis. J Vasc Surg 2005;41:1-9. | 401 | 28.64 | 612 |
| 24 | Brewster DC, Cronenwett JL, Hallett JW, Johnston KW, Krupski WC, Matsumura JS. Guidelines for the treatment of abdominal aortic aneurysms: report of a subcommittee of the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery. J Vasc Surg 2003;37:1106-17. | 393 | 24.56 | 725 |
| 25 | Veith FJ, Baum RA, Ohki T, Amor M, Adiseshiah M, Blankensteijn JD, et al. Nature and significance of endoleaks and endotension: summary of opinions expressed at an international conference. J Vasc Surg 2002;35:1029-35. | 393 | 23.12 | 634 |
| 26 | Leurs LJ, Bell R, Degrieck Y, Thomas S, Hobo R, Lundbom J. Endovascular treatment of thoracic aortic diseases: combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. J Vasc Surg 2004;40:670-9. | 382 | 25.47 | 509 |
| 27 | Rooke TW, Hirsch AT, Misra S, Sidawy AN, Beckman JA, Findeiss LK, et al 2011 ACCF/AHA Focused update of the guideline for the management of patients with peripheral artery disease (updating the 2005 guideline): a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines Developed in Collaboration With the Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society for Vascular Medicine, and Society for Vascular Surgery. J Vasc Surg 2011;54:e32-58. | 362 | 45.25 | 809 |
| 28 | Isselbacher EM. Thoracic and abdominal aortic aneurysms. Circulation 2005;111:816-28. | 341 | 24.36 | 640 |
| 29 | Chaikof EL, Brewster DC, Dalman RL, Makaroun MS, Illig KA, Sicard GA, et al. The care of patients with an abdominal aortic aneurysm: the Society for Vascular Surgery practice guidelines. J Vasc Surg 2009;50:S2-49. | 325 | 32.5 | 589 |
| 30 | Moore WS, Rutherford RB; EVT Investigators. Transfemoral endovascular repair of abdominal aortic aneurysm: results of the North American EVT phase 1 trial. J Vasc Surg 1996;23:543-53. | 325 | 14.13 | 469 |
| 31 | Dake MD, Miller DC, Mitchell RS, Semba CP, Moore KA, Sakai T. The "first generation" of endovascular stent-grafts for patients with aneurysms of the descending thoracic aorta. J Thorac Cardiovasc Surg 1998;116:689-704. | 323 | 15.38 | 539 |

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**Table I.** Continued.

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 32 | Bavaria JE, Appoo JJ, Makaroun MS, Verter J, Yu ZF, Mitchell RS. Endovascular stent grafting versus open surgical repair of descending thoracic aortic aneurysms in low-risk patients: a multicenter comparative trial. J Thorac Cardiovasc Surg 2007;133:369-77. | 321 | 26.75 | 499 |
| 33 | Chaikof EL, Fillinger MF, Matsumura JS, Rutherford RB, White GH, Blankensteijn JD, et al. Identifying and grading factors that modify the outcome of endovascular aortic aneurysm repair. J Vasc Surg 2002;35:1061-6. | 316 | 18.59 | 407 |
| 34 | Buth J, Harris PL, Hobo R, van Eps R, Cuypers P, Duijm L, et al. Neurologic complications associated with endovascular repair of thoracic aortic pathology: incidence and risk factors. A study from the European Collaborators on Stent/Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) registry. J Vasc Surg 2007;46:1103-11. | 299 | 24.92 | 471 |
| 35 | Schanzer A, Greenberg RK, Hevelone N, Robinson WP, Eslami MH, Goldberg RJ, et al. Predictors of abdominal aortic aneurysm sac enlargement after endovascular repair. Circulation 2011;123:2848-55. | 296 | 37 | 401 |
| 36 | van Marrewijk C, Buth J, Harris PL, Norgren L, Nevelsteen A, Wyatt MG. Significance of endoleaks after endovascular repair of abdominal aortic aneurysms: the EUROSTAR experience. J Vasc Surg 2002;35:461-73. | 279 | 16.41 | 428 |
| 37 | Greenberg RK, Lu Q, Roselli EE, Svensson LG, Moon MC, Hernandez AV, et al. Contemporary analysis of descending thoracic and thoracoabdominal aneurysm repair: a comparison of endovascular and open techniques. Circulation 2008;118:808-17. | 272 | 24.73 | 386 |
| 38 | White GH, May J, Waugh RC, Chaufour X, Yu W. Type III and type IV endoleak: toward a complete definition of blood flow in the sac after endoluminal AAA repair. J Endovasc Ther 1998;5:305-9. | 254 | 12.1 | 417 |
| 39 | Volodos NL, Karpovich IP, Troyan VI, Kalashnikova Y, Shekhanin VE, Ternyuk NE, et al. Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction. Vasa Suppl 1991;3:93.[a] | | | 400 |
| 40 | May J, White GH, Yu W, Ly CN, Waugh R, Stephen MS, et al. Concurrent comparison of endoluminal versus open repair in the treatment of abdominal aortic aneurysms: analysis of 303 patients by life table method. J Vasc Surg 1998;27:213-21. | 244 | 11.62 | 369 |
| 41 | Marin ML, Veith FJ, Cynamon J, Sanchez LA, Lyon RT, Levine BA, et al. Initial experience with transluminally placed endovascular grafts for the treatment of complex vascular lesions. Ann Surg 1995;222:449. | 241 | 10.04 | 347 |
| 42 | Lederle FA, Freischlag JA, Kyriakides TC, Matsumura JS, Padberg FT Jr., Kohler TR, et al. Long-term comparison of endovascular and open repair of abdominal aortic aneurysm. N Engl J Med 2012;367:1988-97. | 239 | 34.14 | 375 |
| 43 | Matsumura JS, Brewster DC, Makaroun MS, Naftel DC; Excluder Bifurcated Endoprosthesis Investigators. A multicenter controlled clinical trial of open versus endovascular treatment of abdominal aortic aneurysm. J Vasc Surg 2003;37:262-71. | 236 | 14.75 | 397 |
| 44 | Elefteriades JA, Farkas EA. Thoracic aortic aneurysm: clinically pertinent controversies and uncertainties. J Am Coll Cardiol 2010;55:841-57. | 227 | 25.22 | 375 |
| 45 | Criado FJ, Clark NS, Barnatan MF. Stent graft repair in the aortic arch and descending thoracic aorta: a 4-year experience. J Vasc Surg 2002;36:1121-8. | 226 | 13.29 | 386 |
| 46 | Greenberg R, Resch T, Nyman U, Lindh M, Brunkwall J, Brunkwall P, et al. Endovascular repair of descending thoracic aortic aneurysms: an early experience with intermediate-term follow-up. J Vasc Surg 2000;31:147-56. | 226 | 11.89 | 330 |
| 47 | Mitchell RS, Dake MD, Semba CP, Fogarty TJ, Zarins CK, Liddell RP, et al. Endovascular stent-graft repair of thoracic aortic aneurysms. J Thorac Cardiovasc Surg 1996;111:1054-62. | 226 | 9.83 | 353 |

**Table I.** Continued.

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 48 | Marin ML, Veith FJ, Panetta TF, Cynamon J, Sanchez LA, Schwartz ML, et al. Transluminally placed endovascular stented graft repair for arterial trauma. J Vasc Surg 1994;20:466-73. | 219 | 8.76 | 317 |
| 49 | Buth J, Laheij RJ. Early complications and endoleaks after endovascular abdominal aortic aneurysm repair: report of a multicenter study. J Vasc Surg 2000;31:134-46. | 214 | 11.26 | 358 |
| 50 | Black SA, Wolfe JH, Clark M, Hamady M, Cheshire NJ, Jenkins MP. Complex thoracoabdominal aortic aneurysms: endovascular exclusion with visceral revascularization. J Vasc Surg 2006;43:1081-9. | 212 | 16.31 | 344 |
| 51 | Makaroun MS, Dillavou ED, Wheatley GH, Cambria RP. Five-year results of endovascular treatment with the Gore TAG device compared with open repair of thoracic aortic aneurysms. J Vasc Surg 2008;47:912-8. | 210 | 19.09 | 397 |
| 52 | Matsumura JS, Cambria RP, Dake MD, Moore RD, Svensson LG, Snyder S. International controlled clinical trial of thoracic endovascular aneurysm repair with the Zenith TX2 endovascular graft: 1-year results. J Vasc Surg 2008;47:247-57. | 206 | 18.73 | 283 |
| 53 | Brewster DC, Geller SC, Kaufman JA, Cambria RP, Gertler JP, LaMuraglia GM, et al. Initial experience with endovascular aneurysm repair: comparison of early results with outcome of conventional open repair. J Vasc Surg 1998;27:992-1005. | 205 | 9.76 | 280 |
| 54 | Kato N, Dake MD, Miller DC, Semba CP, Mitchell RS, Razavi MK, et al. Traumatic thoracic aortic aneurysm: treatment with endovascular stent-grafts. Radiology 1997;205:657-62. | 205 | 9.32 | 324 |
| 55 | Fattori R, Nienaber CA, Rousseau H, Beregi JP, Heijmen R, Grabenwöger M, et al. Results of endovascular repair of the thoracic aorta with the Talent Thoracic stent graft: the Talent Thoracic Retrospective Registry. J Thorac Cardiovasc Surg 2006 ;132:332-9. | 204 | 15.69 | 232 |
| 56 | Carpenter JP, Baum RA, Barker CF, Golden MA, Mitchell ME, Velazquez OC, et al. Impact of exclusion criteria on patient selection for endovascular abdominal aortic aneurysm repair. J Vasc Surg 2001;34:1050-4. | 203 | 11.28 | 289 |
| 57 | Hinchliffe RJ, Bruijstens L, MacSweeney ST, Braithwaite BD. A randomised trial of endovascular and open surgery for ruptured abdominal aortic aneurysm—results of a pilot study and lessons learned for future studies. Eur J Vasc Endovasc Surg 2006;32:506-13. | 200 | 15.38 | 280 |
| 58 | Greenberg RK, Clair D, Srivastava S, Bhandari G, Turc A, Hampton J, et al. Should patients with challenging anatomy be offered endovascular aneurysm repair? J Vasc Surg 2003;38:990-6. | 198 | 12.38 | 303 |
| 59 | Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma multicenter study. J Trauma Acute Care Surg 2008;64:561-71. | 197 | 17.91 | 308 |
| 60 | Verhoeven EL, Vourliotakis G, Bos WT, Tielliu IF, Zeebregts CJ, Prins TR, et al. Fenestrated stent grafting for short-necked and juxtarenal abdominal aortic aneurysm: an 8-year single-centre experience. Eur J Vasc Endovasc Surg 2010;39:529-36. | 196 | 21.78 | 252 |
| 61 | Jones JE, Atkins MD, Brewster DC, Chung TK, Kwolek CJ, LaMuraglia GM, et al. Persistent type 2 endoleak after endovascular repair of abdominal aortic aneurysm is associated with adverse late outcomes. J Vasc Surg 2007;46:1-8. | 196 | 16.33 | 296 |
| 62 | Laheij RJ, Buth J, Harris PL, Moll FL, Stelter WJ, Verhoeven EL. Need for secondary interventions after endovascular repair of abdominal aortic aneurysms. Intermediate-term follow-up results of a European collaborative registry (EUROSTAR). Br J Surg 2000;87:1666-73. | 196 | 10.32 | 283 |
| 63 | Greenberg RK, West K, Pfaff K, Foster J, Skender D, Haulon S, et al. Beyond the aortic bifurcation: branched endovascular grafts for thoracoabdominal and aortoiliac aneurysms. J Vasc Surg 2006;43:879-86. | 191 | 14.69 | 264 |

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**Table I.** Continued.

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 64 | Gravereaux EC, Faries PL, Burks JA, Latessa V, Spielvogel D, Hollier LH, et al. Risk of spinal cord ischemia after endograft repair of thoracic aortic aneurysms. J Vasc Surg 2001;34:997-1003. | 191 | 10.61 | 308 |
| 65 | Zarins CK, White RA, Hodgson KJ, Schwarten D, Fogarty TJ. Endoleak as a predictor of outcome after endovascular aneurysm repair: AneuRx multicenter clinical trial. J Vasc Surg 2000;32:90-107. | 191 | 10.05 | 287 |
| 66 | Ohki T, Veith FJ, Shaw P, Lipsitz E, Suggs WD, Wain RA, et al. Increasing incidence of midterm and long-term complications after endovascular graft repair of abdominal aortic aneurysms: a note of caution based on a 9-year experience. Ann Surg 2001;234:323. | 190 | 10.56 | 297 |
| 67 | Yusuf SW, Whitaker SC, Chuter TA, Wenham PW, Hopkinson BR. Emergency endovascular repair of leaking aortic aneurysm. Lancet 1994;344:1645. | 189 | 7.56 | 277 |
| 68 | Peppelenbosch N, Buth J, Harris PL, van Marrewijk C, Fransen G. Diameter of abdominal aortic aneurysm and outcome of endovascular aneurysm repair: does size matter? A report from EUROSTAR. J Vasc Surg 2004;39:288-97. | 182 | 12.13 | 284 |
| 69 | White GH, May J, Petrasek P, Waugh R, Stephen M, Harris J. Endotension: an explanation for continued AAA growth after successful endoluminal repair. J Endovasc Ther 1999;6:308-15. | 181 | 9.05 | 268 |
| 70 | Zarins CK, White RA, Fogarty TJ. Aneurysm rupture after endovascular repair using the AneuRx stent graft. J Vasc Surg 2000;31:960-70. | 180 | 9.47 | 252 |
| 71 | Kan CD, Lee HL, Yang YJ. Outcome after endovascular stent graft treatment for mycotic aortic aneurysm: a systematic review. J Vasc Surg 2007;46:906-12. | 178 | 14.83 | 285 |
| 72 | Sternbergh WC, Carter G, York JW, Yoselevitz M, Money SR. Aortic neck angulation predicts adverse outcome with endovascular abdominal aortic aneurysm repair. J Vasc Surg 2002;35:482-6. | 178 | 10.47 | 257 |
| 73 | Baum RA, Carpenter JP, Golden MA, Velazquez OC, Clark TW, Stavropoulous SW, et al. Treatment of type 2 endoleaks after endovascular repair of abdominal aortic aneurysms: comparison of transarterial and translumbar techniques. J Vasc Surg 2002;35:23-9. | 177 | 10.41 | 250 |
| 74 | Stone DH, Brewster DC, Kwolek CJ, LaMuraglia GM, Conrad MF, Chung TK, et al. Stent-graft versus open-surgical repair of the thoracic aorta: mid-term results. J Vasc Surg 2006;44:1188-97. | 175 | 13.46 | 273 |
| 75 | Chuter TA, Green RM, Ouriel K, Fiore WM, DeWeese JA. Transfemoral endovascular aortic graft placement. J Vasc Surg 1993;18:185-97. | 175 | 6.73 | 282 |
| 76 | Mitchell RS, Miller DC, Dake MD, Semba CP, Moore KA, Sakai T. Thoracic aortic aneurysm repair with an endovascular stent graft: the "first generation". Ann Thorac Surg 1999;67:1971-4. | 174 | 8.7 | 270 |
| 77 | Blum U, Langer M, Spillner G, Mialhe C, Beyersdorf F, Buitrago-Tellez C, et al. Abdominal aortic aneurysms: preliminary technical and clinical results with transfemoral placement of endovascular self-expanding stent-grafts. Radiology 1996;198:25-31. | 174 | 7.57 | 236 |
| 78 | O'Neill S, Greenberg RK, Haddad F, Resch T, Sereika J, Katz E. A prospective analysis of fenestrated endovascular grafting: intermediate-term outcomes. Eur J Vasc Endovasc Surg 2006;32:115-23. | 173 | 13.31 | 261 |
| 79 | Van Marrewijk CJ, Fransen G, Laheij RJ, Harris PL, Buth J. Is a type II endoleak after EVAR a harbinger of risk? Causes and outcome of open conversion and aneurysm rupture during follow-up. Eur J Vasc Endovasc Surg 2004;27:128-37. | 172 | 11.47 | 252 |
| 80 | Greenberg RK, Sternbergh WC, Makaroun M, Ohki T, Chuter T, Bharadwaj P, et al. Intermediate results of a United States multicenter trial of fenestrated endograft repair for juxtarenal abdominal aortic aneurysms. J Vasc Surg 2009;50:730-7. | 171 | 17.1 | 269 |

**Table I.** Continued.

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 81 | Gilling-Smith G, Brennan J, Harris P, Bakran A, Gould D, McWilliams R. Endotension after endovascular aneurysm repair: definition, classification, and strategies for surveillance and intervention. J Endovasc Ther 1999;6:305-7. | 171 | 8.55 | 274 |
| 82 | Becquemin JP, Pillet JC, Lescalie F, Sapoval M, Goueffic Y, Lermusiaux P, et al. A randomized controlled trial of endovascular aneurysm repair versus open surgery for abdominal aortic aneurysms in low-to moderate-risk patients. J Vasc Surg 2011;53:1167-73. | 170 | 21.25 | 269 |
| 83 | Greenberg RK, Chuter TA, Sternbergh WC, Fearnot NE. Zenith AAA endovascular graft: intermediate-term results of the US multicenter trial. J Vasc Surg 2004;39:1209-18. | 170 | 11.33 | 245 |
| 84 | Fairman RM, Criado F, Farber M, Kwolek C, Mehta M, White R, et al. Pivotal results of the Medtronic Vascular Talent Thoracic Stent Graft System: the VALOR trial. J Vasc Surg 2008;48:546-54. | 168 | 15.27 | 258 |
| 85 | Baum RA, Carpenter JP, Cope C, Golden MA, Velazquez OC, Neschis DG, et al. Aneurysm sac pressure measurements after endovascular repair of abdominal aortic aneurysms. J Vasc Surg 2001;33:32-41. | 167 | 9.28 | 264 |
| 86 | Ahn SS, Rutherford RB, Johnston KW, May J, Veith FJ, Baker JD, et al. Reporting standards for infrarenal endovascular abdominal aortic aneurysm repair. J Vasc Surg 1997;25:405-10. | 167 | 7.59 | 258 |
| 87 | Brewster DC, Jones JE, Chung TK, Lamuraglia GM, Kwolek CJ, Watkins MT, et al. Long-term outcomes after endovascular abdominal aortic aneurysm repair: the first decade. Ann Surg 2006;244:426. | 165 | 12.69 | 242 |
| 88 | Inoue K, Hosokawa H, Iwase T, Sato M, Yoshida Y, Ueno K, et al. Aortic arch reconstruction by transluminally placed endovascular branched stent graft. Circulation 1999;100 (Suppl 2):II316. | 165 | 8.25 | 304 |
| 89 | Lumsden AB, Allen RC, Chaikof EL, Resnikoff M, Moritz MW, Gerhard H, et al. Delayed rupture of aortic aneurysms following endovascular stent grafting. Am J Surg 1995;170:174-8. | 164 | 6.83 | 240 |
| 90 | Laborde JC, Parodi JC, Clem MF, Tio FO, Barone HD, Rivera FJ, et al. Intraluminal bypass of abdominal aortic aneurysm: feasibility study. Radiology 1992;184:185-90. | 162 | 6 | 218 |
| 91 | Semba CP, Kato N, Kee ST, Lee GK, Mitchell RS, Miller DC, et al. Acute rupture of the descending thoracic aorta: repair with use of endovascular stent-grafts. J Vasc Interv Radiol 1997;8:337-42. | 160 | 7.27 | 261 |
| 92 | Moore WS, Vescera CL. Repair of abdominal aortic aneurysm by transfemoral endovascular graft placement. Ann Surg 1994;220:331. | 160 | 6.4 | 213 |
| 93 | Ouriel K, Clair DG, Greenberg RK, Lyden SP, O'Hara PJ, Sarac TP, et al. Endovascular repair of abdominal aortic aneurysms: device-specific outcome. J Vasc Surg 2003;37:991-8. | 158 | 9.88 | 248 |
| 94 | Demers P, Miller DC, Mitchell RS, Kee ST, Sze D, Razavi MK, et al. Midterm results of endovascular repair of descending thoracic aortic aneurysms with first-generation stent grafts. J Thorac Cardiovasc Surg 2004;127:664-73. | 157 | 10.47 | 224 |
| 95 | Zarins CK, Bloch DA, Crabtree T, Matsumoto AH, White RA, Fogarty TJ. Stent graft migration after endovascular aneurysm repair: importance of proximal fixation. J Vasc Surg 2003;38:1264-72. | 157 | 9.81 | 245 |
| 96 | Anderson JL, Berce M, Hartley DE. Endoluminal aortic grafting with renal and superior mesenteric artery incorporation by graft fenestration. J Endovasc Ther 2001;8:3-15. | 157 | 8.72 | 237 |
| 97 | Zarins CK, White RA, Moll FL, Crabtree T, Bloch DA, Hodgson KJ, et al. The AneuRx stent graft: four-year results and worldwide experience 2000. J Vasc Surg 2001;33:135-45. | 156 | 8.67 | 291 |
| 98 | Malina M, Ivancev K, Chuter TA, Lindh M, Länne T, Lindblad B, et al. Changing aneurysmal morphology after endovascular grafting: relation to leakage or persistent perfusion. J Endovasc Ther 1997;4:23-30. | 154 | 7 | 209 |

*(Continued on next page)*

**Table I.** Continued.

| Rank | Article | Citations | Citations per year | Google Scholar citations |
|---|---|---|---|---|
| 99 | Matsumura JS, Pearce WH, McCarthy WJ, Yao JS; EVT Investigators. Reduction in aortic aneurysm size: early results after endovascular graft placement. J Vasc Surg 1997;25:113-23. | 151 | 6.86 | 198 |
| 100 | Hobo R, Kievit J, Leurs LJ, Buth J. Influence of severe infrarenal aortic neck angulation on complications at the proximal neck following endovascular AAA repair: a EUROSTAR study. J Endovasc Ther 2007;14:1-11. | 151 | 12.58 | 201 |

[a]As discussed, these articles could not be found in the Web of Science database. A citation count was taken from Google Scholar alone, and they were excluded from all figures.

**Google Scholar comparison.** The results from Web of Science were cross-checked and compared with Google Scholar, which revealed a number of missing studies by Parodi and Volodos. The first is "Transfemoral intraluminal graft implantation for abdominal aortic aneurysms," published in 1991 by J.C. Parodi in *Annals of Vascular Surgery*.[3] The second is "Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction," also published in 1991 by N.L. Volodos in *Vasa Supplementum*. Parodi's paper is the most cited article according to Google Scholar (n = 3886), while Volodos is also highly cited (n = 400). Volodos' original Russian article, "A case of distant transfemoral endoprosthesis of the thoracic artery using a self-fixing synthetic prosthesis in traumatic aneurysm," published in *Grudnaia Khirurgiia* in 1988, is also absent. No articles published by *Vasa Supplementum* or *Annals of Vascular Surgery* before 1995 and nothing at all by *Grudnaia Khirurgiia* could be found in the Web of Science database.

Google Scholar generally had higher citation counts for each article, but the overall trend was otherwise consistent in both total numbers and frequency of citations.

**Journals.** Twenty journals contributed to the list (Table II), with the *Journal of Vascular Surgery* providing almost half (n = 46) of the top 100. The *New England Journal of Medicine* was the second most prolific journal, providing eight papers. The *New England Journal of Medicine* and *Lancet* were the two journals with the highest impact factor (72.406 and 47.831, respectively), whereas the *Journal of Vascular Surgery* had an impact factor of 3.536. Almost half (n = 9) of the journals contributing to the list were published by Elsevier.

**Authorship.** Thirty-nine authors contributed 4 or more articles to the list (Table III), with 15 authors contributing 7 or more and 2 authors (R.S. Mitchell and J. Buth) reaching 10. C.K. Zarins and R.K. Greenberg were the most prevalent primary authors with five publications each as first author.

**Country and institution of origin.** Twelve countries were represented in the top 100 list (Fig 1), with the United States (n = 62) by far the most prevalent. The United Kingdom and The Netherlands, from which the DREAM and EUROSTAR groups emerge, contributed 11 and 10 papers, respectively. Germany, Australia, and Argentina feature a handful of times each, whereas France, Italy, Sweden, Taiwan, Ukraine, and Japan each contributed one article.

In keeping with the countries of origin, the most prolific institutions were Stanford University (n = 12) and the Cleveland Clinic (n = 9), both based in the United States. The University of Pennsylvania (n = 6), Massachusetts General Hospital (n = 5), and Emory University (n = 4) are other noteworthy American centers. Internationally, the countries represented were often centers for the multicenter trial groups. The EUROSTAR database was represented by its data registry center at Catharina Hospital (n = 5) and its secretariat at Royal Liverpool University Hospital (n = 4). The DREAM trial group was based at University Medical Center Utrecht (n = 4), and the EVAR trial ran at Imperial College London (n = 4). The University of Sydney is the sole Australian site (n = 4). A number of other institutions provided three or fewer articles to the top 100 list.

**Topics.** The primary subject matter of the articles was categorized, with the largest representation (n = 28) being those evaluating efficacy, morbidity, mortality, and prognosis in EVAR without comparing it directly with traditional open repair techniques. Included in this was one RCT comparing EVAR and no intervention and much of the prospective and retrospective analyses based on data from the EUROSTAR registry. A sizable number (n = 17) compared EVAR and open repair, which included 11 RCTs. Twenty-one articles in total primarily examined TEVAR, but comparatively few (n = 5) actually compared TEVAR with traditional open repair of thoracic aneurysms, and there were no RCTs in the top 100 list.

Twenty-nine papers primarily examined the complications or prognosis after EVAR or TEVAR, with more than a third (n = 11) of those being mostly concerned with

**Table II.** Journals contributing to the top 100 list

| Journal | No. of top 100 articles | Impact factor |
|---|---|---|
| Journal of Vascular Surgery | 46 | 3.536 |
| New England Journal of Medicine | 8 | 72.406 |
| Journal of Thoracic and Cardiovascular Surgery | 5 | 4.446 |
| Circulation | 5 | 19.309 |
| Journal of Endovascular Surgery | 5 | 5.467 |
| European Journal of Vascular and Endovascular Surgery | 5 | 4.061 |
| Lancet | 4 | 47.831 |
| Annals of Surgery | 4 | 8.98 |
| Journal of the American College of Cardiology | 3 | 19.896 |
| Radiology | 3 | 7.296 |
| Annals of thoracic Surgery | 2 | 3.7 |
| Journal of Endovascular Therapy | 2 | 2.838 |
| JAMA: Journal of the American Medical Association | 1 | 44.405 |
| European Heart Journal | 1 | 20.212 |
| British Journal of Surgery | 1 | 5.899 |
| Journal of Trauma, Injury, Infection, and Critical Care | 1 | 2.961 |
| Journal of Vascular and Interventional Radiology | 1 | 2.78 |
| American Journal of Surgery | 1 | 2.612 |
| Annals of Vascular Surgery | 1 | 1.145 |
| Vasa Supplementum | 1 | N/A[a] |

*N/A*, Not applicable.
[a]No longer in print, no recent impact factors to list.

endoleaks, a spectrum of complications unique to endovascular treatment of aortic disease. Miscellaneous articles included overviews of current knowledge or controversies regarding aneurysms without any experimental data, and two articles on reporting standards were also included.

**Level of evidence.** Table IV breaks down the top 100 articles by study type and level of evidence based on the National Health and Medical Research Council of Australia[13] and University of Oxford Centre for Evidence-Based Medicine[14] guides. A high level of evidence is reflected in the 7 guidelines (level I/1, National Health and Medical Research Council of Australia/Centre for Evidence-Based Medicine), 12 RCTs (level II/2), and 45 prospective papers (level III-2/3) featured. This is reflective of the many prospective data collection efforts across the globe. Many of the 17 retrospective articles (level III-3/4) were also based on prospectively collected data, whereas the volume of highly cited low-level evidence is very small in comparison.

## DISCUSSION

Research into endovascular repair of thoracic and abdominal aneurysms has been thorough and expansive in the 2½ decades since it was introduced. This bibliometric analysis highlights the still increasing volume of research as well as the high quality of evidence and important multinational contributions to the body of knowledge surrounding EVAR and TEVAR.

Compared with citation analyses in other fields, the total number of citations per article is fewer, with the top cited studies in emergency abdominal surgery, urology, and intracranial aneurysms reaching 1569, 1435, and 1947 citations, respectively.[9,15,16] This may, however, be a reflection of the maturity of those fields, with the bulk of their top-cited articles originating from before the turn of the century. In contrast, the majority of the top 100 cited EVAR and TEVAR papers were published in the last 15 years and compare favorably in the rate of citations. The average citations per year in intracranial aneurysms was 22.4, which is the same as in EVAR and TEVAR. The most frequently cited article in emergency abdominal surgery averaged 40 citations per year in comparison to 108.3 for EVAR and TEVAR. Fig 2 also shows that 2016 had the greatest number of total citations for all articles in the top 100 despite that the latest article in the list was published in 2014 and only 10 articles were published in the preceding 5 years. This suggests that the volume of research into EVAR and TEVAR is stable, if not accelerating, while building on the work established beforehand.

A glaring deficiency in the list is the lack of non-English-language articles. Although this is not unexpected, given the ubiquity of the English language in science, it is brought into focus by the pattern of recognition of

**Table III.** Authors who contributed four or more articles to the top 100 list

| Author | No. of articles | Position on author list |
|---|---|---|
| Mitchell RS | 10 | First (2), third (2), fourth (1), fifth (2), sixth (1), ninth (1), twelfth (1) |
| Buth J | 10 | First (1), second (4), third (2), fifth (2), seventh (1) |
| Zarins CK | 9 | First (5), fifth (2), twelfth (1), twenty-seventh (1) |
| Harris PL | 9 | First (1), second (2), third (4), fourth (1), eighth (1), eleventh (1) |
| Veith FJ | 8 | First (1), second (3), fifth (1), ninth (1), tenth (1), eleventh (1) |
| Greenberg RK | 8 | First (5), second (2), third (1) |
| Miller DC | 8 | First (1), second (3), third (2), sixth (1), seventh (1) |
| Dake MD | 8 | First (2), second (2), third (2), sixth (1), seventh (1) |
| Matsumura JS | 8 | First (3), third (1), fourth (1), fifth (1), sixth (1), seventh (1) |
| May J | 7 | First (1), second (2), third (1), fourth (1), eighth (1), tenth (1) |
| Cambria RP | 7 | Second (1), fourth (2), seventh (3), eighth (3) |
| White RA | 7 | Second (4), fifth (1), seventeenth (1), twenty-fifth (1) |
| Brewster DC | 7 | First (3), second (3), third (3) |
| White GH | 7 | First (3), second (1), fourth (1), fifth (1), twenty-fourth (1) |
| Makaroun MS | 7 | First (2), third (3), fourth (1), nineteenth (1) |
| Semba CP | 6 | First (1), third (2), fourth (3) |
| Fogarty TJ | 6 | Third (1), fourth (1), fifth (1), sixth (1), seventh (1), eighth (1) |
| Blankensteijn JD | 6 | First (1), second (2), sixth (2), ninth (1), tenth (1) |
| Chuter TA | 6 | First (1), second (2), third (2), fifth (1), eighth (1) |
| Powell JT | 5 | Second (1), third (1), fourth (1), fifth (2) |
| Fairman RM | 5 | First (1), seventh (1), eighth (1), ninth (2) |
| Chaikof EL | 5 | First (3), third (1), fifth (1) |
| Svensson LG | 5 | First (1), fourth (1), fifth (1), eleventh (1), seventeenth (1) |
| Parodi JC | 5 | First (2), second (1), eleventh (1), twentieth (1) |
| Rutherford RB | 4 | Second (2), fourth (1), eleventh (1) |
| Kee ST | 4 | Third (2), fourth (1), seventh (1) |
| Greenhalgh RM | 4 | First (4) |
| LaMuraglia GM | 4 | Fourth (2), sixth (2) |
| Thompson SG | 4 | Fourth (1), fifth (1), seventh (2) |
| Ohki T | 4 | First (1), third (3), fourth (4), fourteenth (1) |
| Laheij RJ | 4 | First (1), second (2), third (1), sixth (1) |
| Baum RA | 4 | First (2), second (2) |
| Hodgson KJ | 4 | Third (1), fourth (1), sixth (1), twelfth (1) |
| Ouriel K | 4 | First (1), third (1), ninth (1), twelfth (1) |
| Brown LC | 4 | Second (4) |
| Verhoeven EL | 4 | First (1), second (2), fifth (1), sixth (1) |
| Kwolek CJ | 4 | Third (1), fourth (1), fifth (2) |
| Lytle BW | 4 | Eleventh (1), twelfth (2), thirteenth (1) |
| van Marrewijk C | 4 | First (2), fourth (1), fifth (1) |

N.L. Volodos' work. His most cited article, "Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction," is not his first article on the topic but rather his first in English. Volodos published "A case of distant transfemoral endoprosthesis of the thoracic artery using a self-fixing synthetic prosthesis in traumatic aneurysm" in 1988; however, this Russian-language article has only 143 citations in Google Scholar to this day, despite truly being a seminal piece on the topic. This is undeniable proof of the large advantage English publications have in gaining international recognition.

A major driver of citations for an article is the impact factor of the journal in which it is published. While the *Journal of Vascular Surgery* contributed nearly half of the top 100 most cited articles, only one of those was in the top 10 most cited. The journals with an impact factor exceeding 10 (*New England Journal of Medicine*, *Lancet*,

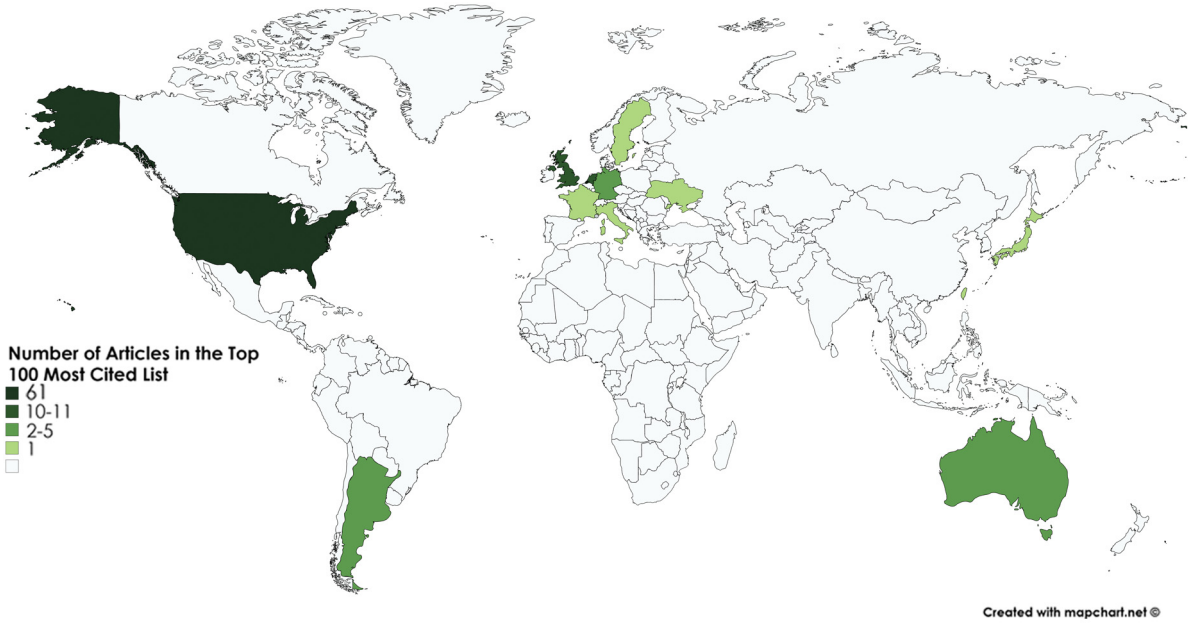


**Fig 1.** Map of countries represented in the top 100 most cited list.

**Table IV.** Level of evidence of the articles in the top 100 list

| Level of evidence | | Article type | No. of articles |
|---|---|---|---|
| NHMRC | CEBM | | |
| I | 1 | Guidelines | 7 |
| II | 2 | RCT | 12 |
| III-2 | 3 | Original prospective | |
| | | Clinical | 43 |
| | | Animal | 2 |
| III-3 | 4 | Original retrospective | |
| | | Clinical | 17 |
| IV | | Case series | 6 |
| | 5 | Expert opinion | 2 |
| | | Case report | 1 |
| | | Review | 7 |
| N/A | | Reporting standards | 2 |

*CEBM*, University of Oxford Centre for Evidence-Based Medicine; *N/A*, not applicable; *NHMRC*, National Health and Medical Research Council of Australia; *RCT*, randomized controlled trial.

*Journal of the American Medical Association*, *European Heart Journal*, *Journal of the American College of Cardiology*, and *Circulation*) represent only 22 of the articles in the top 100 but 13 of the top 20. The strength of articles published in higher impact journals is clearly demonstrated in Fig 3, which shows a positive correlation between the impact factor of a journal and the average number of citations per year the articles it publishes receives.

Also noteworthy is Elsevier's contribution to the list as a publisher. Whereas Elsevier is well known to have a strong portfolio of journals, it may indicate a particular strength in endovascular interventions.

The authorship of the most highly cited papers in EVAR and TEVAR is substantially more concentrated and collaborative than in other fields. Nine authors published more than seven articles to make the top 100 list, whereas 40 authors contributed more than three. In contrast, only two authors published more than seven and only five published more than three articles on the topic of intracranial aneurysms, with similar trends in plastic surgery, urology, and radiology.[15-18] This is likely reflective of the handful of large trial groups that subsequently published multiple papers together with collaborative authors. The EUROSTAR registry produced seven papers in the cited list and included highly cited authors J. Buth (n = 10) and P.L. Harris (n = 9). The two most prolific American centers also each had core authors who appear several times, such as R.S. Mitchell (n = 10), C.K. Zarins (n = 9), D.C. Miller (n = 8), and M.D. Dake (n = 8) of Stanford University and R.K. Greenberg (n = 8) of the Cleveland Clinic. Finally, there were also a number of long-term studies with multiple publications headed by the same author. These include the EVAR trial, based at Imperial College London, which produced four articles all headed by R.M. Greenhalgh (n = 4), and the GORE TAG trial, which has three entries all involving M.S. Makaroun (n = 7).

Alongside this pattern of authorship, the number of institutions was also more concentrated than in similar analyses. Ten centers contributed four or more articles to the list, whereas only three matched that number in general radiology,[18] five in urology,[15] and three in neurointerventional radiology.[19] A clear pattern emerges here of a handful of centers capturing long-term data and turning that into multiple high-quality publications over time. The EVAR trial exemplifies this with four highly

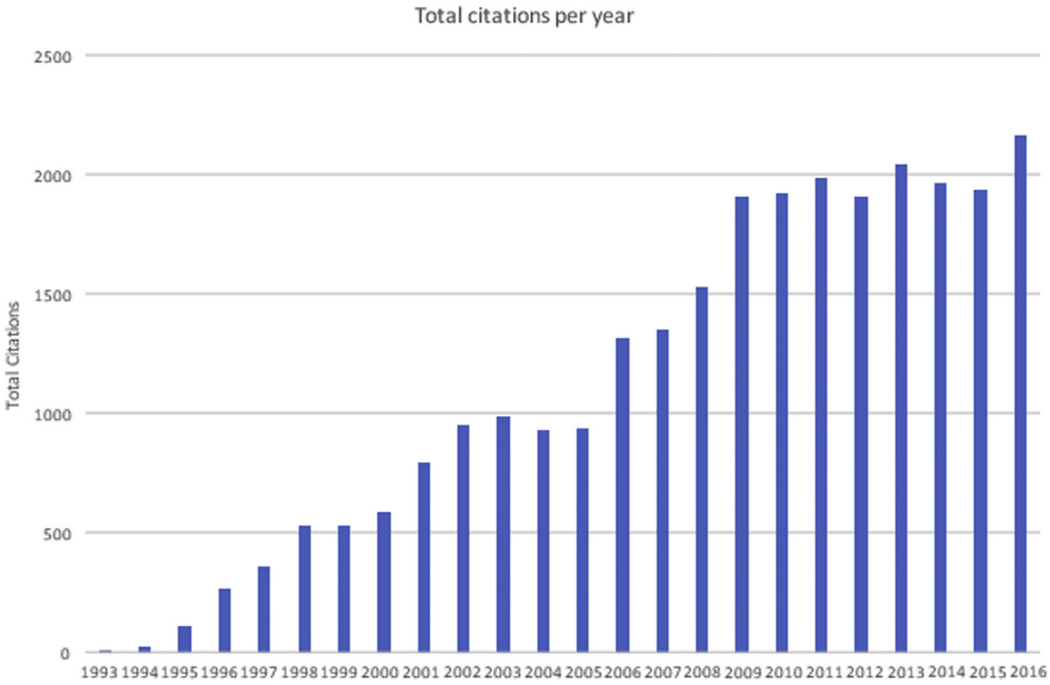


**Fig 2.** Total citations per year of all articles in the top 100.

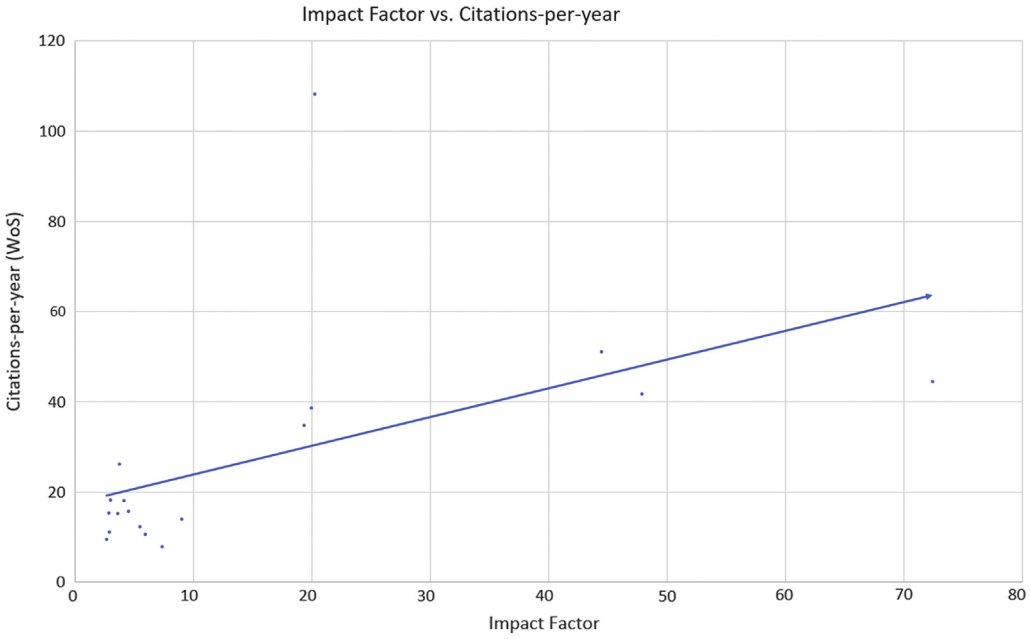


**Fig 3.** Impact factor of a journal vs the average number of citations per year. *WoS,* Web of Science.

cited RCTs published during a 6-year time frame. The DREAM trial is similar, with three highly cited works during a 6-year period. This does expose those trials to perpetuating systemic biases over their life span.

The level of evidence in EVAR is robust, with the aforementioned 6 sets of guidelines and 12 RCTs, many of them highly cited. The earliest guidelines, published in 2005, already had nearly 10 years of existing prospective and controlled data at that time to use, and the ongoing research only strengthened the evidence when many of the guidelines were revised in 2010. The evidence base in TEVAR is less complete, with only one guideline and no RCTs having been published on thoracic aneurysms. While there is a lack of highly cited, controlled data, the studies on TEVAR are primarily large, prospective cohort studies, including 5-year follow-up conducted by

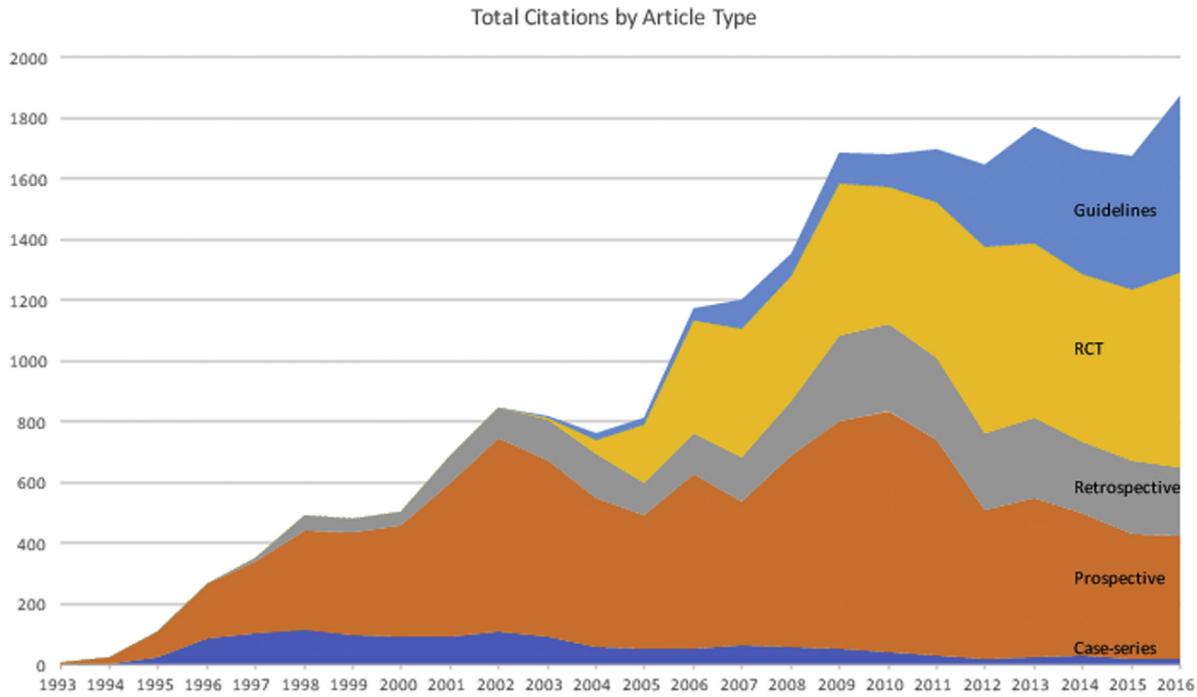


**Fig 4.** Total citations per year by article type. *RCT,* Randomized controlled trial.

Greenberg et al[20] at the Cleveland Clinic and 5-year follow-up by Dake[21] at Stanford University. Large, consecutive data sets such as these and the EUROSTAR program for EVAR can provide significant, meaningful information, especially when RCTs are less feasible.

Furthermore, as previously discussed, the publications in this list are concentrated in a handful of institutions, and this is most evident in the higher level evidence. The 12 RCTs in the top 100 list are in actual fact only 6 trials, some of which have published multiple follow-up papers. This means that the variety and potential effectiveness of the most cited evidence in EVAR and TEVAR are less than they would appear at first glance.

Fig 4 shows, in brief, the chronology and impact of the research performed in EVAR and TEVAR. Initially, small case series and prospective observational studies are produced. As those data are collected, retrospective analyses can be performed and reported on, although they are not as widely cited as the ongoing prospective efforts. The first guidelines and RCTs begin to appear a decade later, only after a significant body of evidence is collected, but they are quickly popularly cited. At the 20-year mark, despite there being significantly more prospective and retrospective articles, the level 1 and level 2 (Centre for Evidence-Based Medicine) evidence is more heavily cited, indicating the maturity of the research into EVAR and TEVAR.

The importance and impact of high-quality articles are also reflected in the rapid rate at which they acquire citations. A citation analysis will naturally preferably capture and rank older studies as they have had more time to be cited by subsequent literature. This can be addressed by looking at the average citations per year instead of the total citations. According to Web of Science, the 10 most frequently cited articles were all either level I or level II evidence, whereas Google Scholar includes Parodi's original experimental studies but is otherwise in agreement. It is particularly notable that the most frequently cited article according to both databases is the "2014 ESC Guidelines on the diagnosis and treatment of aortic diseases," which is also the newest article in the list and ranks much lower in total citations. Analyzing the rate of citations for an article can highlight those works of seminal importance or high impact that would otherwise be overshadowed by older articles that have had more time to be cited.

This analysis is hindered by some limitations. First and foremost, any citation analysis will inherently bias itself toward larger, more prestigious journals as they are the most widely read, distributed, and cited. This issue also self-perpetuates; as higher impact factor journals publish highly cited articles, they will attract more notice and further shadow important work published in smaller journals. The concentration of articles from the *Journal of Vascular Surgery* may be reflective of this. Second, a citation analysis inherently biases toward older, more established articles that have been heavily referenced. The direction of new research, contemporary trials, and shifting perspectives cannot be captured as they simply have not yet had time to be cited in the literature. This has been partially rectified by looking at the rate of citations instead of total citation count, but the lack of publications in the last 5 years shows the potential for new

studies to have not been included in the top 100 most cited list. Third, self-citation will color the search of any bibliometric analysis. This may be especially problematic on this particular topic as there is a concentration of authors and collaborative groups that may cite their own or concurrent research. Consequently, the top 100 may represent a more homogeneous selection of publications and leave out important trials coming from smaller groups. Finally, the literature search is entirely reliant on the integrity of the databases to attain the top 100 most cited articles, which leaves it vulnerable to missing papers. Special consideration should be taken for older and non-English-language articles, which seem particularly prone to being excluded from databases. In this case, it appears that the Web of Science database did not begin incorporating *Annals of Vascular Surgery* until 1995 and never properly indexed *Vasa Supplementum* or *Grudnaia Khirurgiia* at all. This limitation was partly addressed by perusing the articles themselves for notably referenced papers and cross-referencing with the original search, but this is manually intensive and not methodical. Google Scholar should be looked to as an up-and-coming tool for clinicians in conjunction with other traditional databases. Future bibliometric studies would ideally be able to compare Web of Science with an alternative database that can also sort by citation count and automatically generate the same data. This would greatly increase the robustness of the literature search and reliability of the analysis.

## CONCLUSIONS

This bibliometric analysis compiles a comprehensive list of the 100 most cited publications on the topic of endovascular treatment of abdominal and thoracic aortic aneurysms. Through a quantitative analysis, it first demonstrates the impact of the pivotal experiments of Parodi and Volodos to demonstrate the feasibility of endovascular stent grafting. It then follows the subsequent international efforts to produce strong prospective and randomized data through registries such as EUROSTAR and trial groups such as DREAM and EVAR. Finally, it highlights the strong guidelines, built on a decade of longitudinal research, that guide clinicians in their approach to EVAR and TEVAR today.

## AUTHOR CONTRIBUTIONS

Conception and design: ML, HA
Analysis and interpretation: KZ, JM, KP, HK, ML, DB, RC, JH, HA
Data collection: KZ, JM, KP
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## A HIGH IMPACT FACTOR ISN'T EVERYTHING AND IT TAKES TIME TO BE APPRECIATED



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The aim of a bibliometric analysis is to identify key publications (assessed by the most cited and, thereby, assumed most influential) to assess trends, strengths, and gaps in knowledge that might help the physician focus on next steps. Does this article provide the reader with this type of information?

This is an unfamiliar type of analysis for most vascular surgeons. It provides a historical overview of a particular focus of clinical work and insight into what has helped to shape our current perspective of care. It does stress the early work of pioneers in the field, which is oft overlooked by high impact journals and may highlight the critical niche of small specialty and even non-English language-based journals. The authors have attempted to present this aspect of early development, but obviously this was a manual process rather than citation-based process and notes how this type of bibliometric analysis can easily overlook such seminal work. It confirms that a unique field of clinical treatment follows a common evolution from initial report to safety/efficacy reports, case series, retrospective, then prospective data driven articles, and finally randomized controlled trials. The level of evidence is continually increasing to allow the clinician to provide "best care" based on data. When the field has sufficiently matured, practice guidelines are developed and endovascular aortic repair has reached this pinnacle in about 25 years. The guidelines are often a late addition to the field, so volume citation is not as robust as older articles, but the rate of citation is impressive demonstrating their use in practice. It demonstrates that this treatment approach has matured to the point of clinical acceptance with work now concentrating on perfecting device performance and minimizing potential complications (endoleak, occlusion, etc). In the world of aortic endovascular treatment, this study confirms that vascular surgeons conceived, first initiated, and continue to develop the field as documented by publications in high impact journals and lead in volume by the *Journal of Vascular Surgery*.

For the clinical researcher, it highlights the importance of publishing your experiences during the early stages of treatment development since it helps push the field forward. Currently, providing insights by your work into improving endograft device performance and the elimination of potential complications will provide the next advances we need in the field. Randomized controlled trials contribute high-level evidence for patient care and should be supported by your involvement whenever possible. Societal practice guidelines are highly cited and provide colleagues with "best current care" based on "best available data." These efforts demand your participation when offered.

Such an article as this can provide some valuable insights but is obviously a high-level view. It is limited by the databases used and the fact that citation is driven by research interests that might not be focusing on the most critical issues. It is a time-sensitive analysis. The authors provide some detail regarding limitations, which should be read with care.

*The opinions or views expressed in this commentary are those of the authors and do not necessarily reflect the opinions or recommendations of the Journal of Vascular Surgery or the Society for Vascular Surgery*