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ORIGINAL ARTICLE

Retrospective Study

100 classic papers of interventional radiology: A citation analysis

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Abstract

AIM: To define the 100 citation classic papers of interventional radiology.

METHODS: Using the database of Journal Citation Reports the 40 highest impact factor radiology journals were chosen. From these journals the 100 most cited interventional radiology papers were chosen and analysed.

RESULTS: The top paper received 2497 citations and the 100th paper 200 citations. The average number of citations was 320. Dates of publication ranged from 1953 - 2005. Most papers originated in the United States (*n* = 67) followed by Italy (*n* = 20) and France (*n* = 10). Harvard University (*n* = 18) and Osped Civile (*n* = 11) were the most prolific institutions. Ten journals produced all of the top 100 papers with "Radiology" and "AJR" making up the majority. SN Goldberg and T Livraghi were the most prolific authors. Nearly two thirds of the papers (*n* = 61) were published after 1990.

CONCLUSION: This analysis identifies many of the landmark interventional radiology papers and provides a fascinating insight into the changing discourse within the field. It also identifies topics, authors and institutions which have impacted greatly on the specialty.

Key words: Interventional radiology; Citation classic; Radiology; Citation; Citation analysis; Classic papers

Core tip: Interventional radiology is a young and rapidly evolving specialty. This study defined and analysed the 100 most cited interventional radiology papers identifying much of the landmark interventional radiology research and providing a fascinating insight into the changing discourse within the field. It also identified the topics, authors and institutions which have impacted greatly on the specialty.

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INTRODUCTION

A citation is the intellectual acknowledgement of a published or unpublished source in order to substantiate fact. Whilst the intellectual acknowledgement that one paper gives to another is known as a reference, the acknowledgement that one paper receives from another is known as a citation[1]. The field of citation analysis uses the citation rate of a paper as a surrogate marker of a paper's recognition and impact within its biomedical field, the more citations that a paper receives, the greater that paper's impact and recognition[2]. The most cited papers within a specialty can be defined as that specialty's classic papers, with the 100 most cited papers representing the "best of" of that specialty[3]. Recent studies have analysed the highly cited papers in other specialties and produced "best of" lists of the top 100 classic papers[4-6]. From these studies it is clearly evident that highly cited works in a particular field often represent the landmark papers, seminal advances and technical innovations of that specialty. However there are also limitations in using the citation rate of a paper alone to define that paper's scientific quality and impact. Whether a paper is cited by another author can depend upon various factors and biases some of which can lead to citations which are not wholly appropriate[7]. Despite these limitations, citation analysis remains a well recognised method of objectively identifying classic papers within a specialty.

The purpose of this study is to identify and analyse the 100 most cited papers within the specialty of interventional radiology - the 100 citation classics. This will allow the topics, authors and institutions which have impacted greatly on this rapidly evolving specialty to be reviewed whilst also critically evaluating the strengths and weaknesses of citation analysis as a method of defining a paper's quality and impact within its specialty.

MATERIALS AND METHODS

Using the database of Journal Citation Reports, 40 radiology journals were chosen for analysis from the subcategory of "Radiology, Nuclear Medicine and Medical Imaging" (Table 1). The subcategory of "Radiology, Nuclear Medicine and Medical Imaging" covers a broad range of journals and therefore excluded from our selection were those journals dealing purely with nuclear medicine, those dealing with basic imaging science and physics as well as radiotherapy journals.

These 40 journals were then analysed using the Science Citation Index of the Institute of Scientific Information and the 100 most cited interventional radiology papers were chosen. Each of the papers was categorised by body system involved, interventional procedure performed, country of origin, institution of origin, author of paper and year of publication.

Statistical analysis

No biostatistics were used in this study.

RESULTS

Table 2 lists the 100 most cited interventional radiology papers in descending order according to the number of citations received.

Table 3 below summarises some of the analysed characteristics of the 100 most cited papers in inter ventional radiology.

The top paper received 2497 citations whilst the 100th paper in the list was cited 200 times. Seven papers received 500 citations or more with the average number of citations being 320.

The oldest paper is Seldinger's 1953 seminal work on the technique of percutaneous arteriography and this paper also occupies first place in this top 100 list. The most recent paper is published in 2005 by Goldberg *et al*[8]. This is one of Goldberg's six 1st name papers in this list whilst he is also a named author on another nine papers. Nine persons were named authors on four or more papers.

The papers were published between 1953 and 2005. Two thirds of the papers (n = 61) were published after 1990 with just 5 originating before 1970.

The 100 papers originated from just seven countries. The vast majority of the papers (n = 67) originated in the United States followed by Italy (n = 20) and France (n = 10).

Eleven institutions produced more than two publications in the top 100. Harvard University (United States) tops the list with 18 publications followed by Osped Civile (Italy) with 11 publications. Several multicentre studies spanned more than one country or institution. For papers published from these studies all countries or institutions involved have been credited.

The most cited papers in interventional radiology were published in 10 specialist radiology journals with nearly two thirds published in *Radiology* (n = 62) and a fifth (n = 20) published in the *American Journal of Roentgenology*. No papers originated from the high impact factor general medical journals analysed.

The interventional technique of radiofrequency ablation is well represented when the papers are broken down by procedure, with 29 entries in the top 100. This is followed by angiography and embolization with 14 papers a piece and subsequently image guided biopsy with 11 papers. The hepatobiliary system is the most studied body system with 30 papers focusing upon it and this is followed by 20 papers focusing upon the vascular system. Although categorising these papers

Table 1 Radiology journals analysed in order of 5 year impact factor

Rank	Journal	5 yr impact factor
1	*Neuroimage*	6.817
2	*Radiology*	6.409
3	*JACC Cardiovascular Imaging*	5.528
4	*Circulation Cardiovascular Imaging*	4.757
5	*Investigative Radiology*	4.328
6	*Magnetic Resonance in Medicine*	3.885
7	*Radiographics*	3.602
8	*American Journal of Neuroradiology*	3.413
9	*European Radiology*	3.384
10	*American Journal of Roentgenology*	2.979
11	*Journal of Magnetic Resonance Imaging*	2.97
12	*European Journal of Radiology*	2.673
13	*Neuroradiology*	2.556
14	*Journal of Vascular and Interventional Radiology*	2.433
15	*Radiologic Clinics of North America*	2.404
16	*British Journal of Radiology*	2.354
17	*Academic Radiology*	2.201
18	*Magnetic Resonance Imaging*	2.144
19	*Neuroimaging Clinics of North America*	2.109
20	*Korean Journal of Radiology*	1.863
21	*Cardiovascular and Interventional Radiology*	1.792
22	*Clinical Radiology*	1.754
23	*Abdominal Imaging*	1.716
24	*International Journal of Cardiovascular Imaging*	1.682
25	*Journal of Thoracic Imaging*	1.592
26	*Journal of Neuroimaging*	1.586
27	*Journal of Computer Assisted Tomography*	1.551
28	*Paediatric Radiology*	1.535
29	*Radiologica Medica*	1.448
30	*Skeletal Radiology*	1.443
31	*Acta Radiologica*	1.312
32	*Seminars in Musculoskeletal Radiology*	1.201
33	*Journal of Neuroradiology*	1.148
34	*Seminars in Ultrasound, CT and MRI*	1.005
35	*Clinical Imaging*	0.869
36	*Seminars in Roentgenology*	0.823
37	*Current Medical Imaging Reviews*	0.776
38	*Canadian Association of Radiologists Journal*	0.665
39	*Journal de Radiologie*	0.51
40	*Der Radiologe*	0.454
41	*Interventional Neuroradiology*	0.173
42	*Clinical Neuroradiology*	-
43	*Diagnostic and Interventional Radiology*	-
44	*Seminars in Interventional Radiology*	-

by body system studied or interventional procedure performed gives a useful overall picture of the studies included in this list, it is obvious that the two categories are interlinked. Closer inspection reveals 10 papers in the top 20, and 26 papers in the top 100 focusing upon liver metastases. Most look specifically at ablation or embolization of these metastases and this goes some way to explaining why the hepatobiliary system and radiofrequency ablation are so highly represented.

DISCUSSION

This list of the 100 citation classic papers of inter ventional radiology provides a fascinating insight into the history and development of the specialty over the last 60 years. It identifies many of the topics, authors and institutions which have contributed most heavily to the field and includes many landmark papers.

Many authors featuring prominently here might be considered to be the forerunners in the development interventional radiology as a specialty. The impact of authors such as Seldinger, Judkins, Gianturco, vanSonnenburg and Mueller cannot be underestimated and techniques and equipment bear their names to this day.

Despite the prominence of these authors, it must be noted that inclusion in this list of the 100 citation classics of interventional radiology does not necessarily mean that the cited authors contributed to the development of a particular technique. Goodwin's paper which is in 89th place in this top 100 list is a good example. This paper dealt with preliminary results of uterine artery embolization, but it was not him who introduced this technique, but Ravina *et al*[9] 1995. It is also surprising that important developments such as the pioneering work of Serbinenko and Djindjian in the development of intracerebral embolization, Porstman's occlusion technique of the Ductus arteriosus, and Volodos work in the development of the first aortic endograft are not covered by this citation analysis. This is likely due to the fact that their papers were published outside of the specialist radiology journals and therefore are not captured by this study. This flaw is covered later in the discussion section.

It is interesting to see the changing topics covered by papers over the last 60 years which mirror the history of interventional radiology. The very early papers, representing the birth of the specialty, focus almost solely on cardiac and vascular interventional techniques. As time progresses the variety of interventions rises to include neurological and musculoskeletal procedures and there is also increasing focus on techniques dealing with malignant metastatic disease. This represents interventional radiology branching out into oncology where it now plays an important role within the multidisciplinary structure. Some other techniques, such as coronary angiography, began as the role of the interventional radiologist but have now been subsumed by other specialties and consequently recent papers concerning these techniques are now likely to be published outside of radiology journals.

Just under two thirds of the papers were published after 1990 which is surprising as it is natural to assume that older papers will accumulate more citations. However this is only true to a certain degree. It will generally take 1-2 years after publication for a paper to be cited. This is followed by an increase in citation rate up to a maximum point which is usually between 5 and 10 years after publication. After this maximum point the rate of citation gradually starts to decline[1]. This has two main implications; firstly older papers do not continue to accumulate citations in proportion to their age, this is why the top of this list is not solely made up

Table 2 The 100 most cited interventional radiology papers of all time

Rank	Paper	No. of citations
1	Seldinger SI. "Catheter replacement of the needle in percutaneous arteriography; a new technique," *Acta Radiologica* 39, no. 5 (May 1953): 368-376	2497
2	Judkins MP. "Selective coronary arteriography. I. A percutaneous transfemoral technic," *Radiology* 89, no. 5 (November 1967): 815-824	1071
3	Livraghi T, Goldberg SN, Lazzaroni S, Meloni F, Solbiati L, Gazelle GS. "Small hepatocellular carcinoma: treatment with radio-frequency ablation versus ethanol injection". *Radiology* 210, no. 3 (March 1999): 655-661	735
4	Yamada R, Sato M, Kawabata M, Nakatsuka H, Nakamura K, Takashima S. "Hepatic artery embolization in 120 patients with unresectable hepatoma," *Radiology* 148, no. 2 (August 1983): 397-401	625
5	Livraghi T, Giorgio A, Marin G, Salmi A, de Sio I, Bolondi L, Pompili M, Brunello F, Lazzaroni S, Torzilli G. "Hepatocellular carcinoma and cirrhosis in 746 patients: long-term results of percutaneous ethanol injection," *Radiology* 197, no. 1 (October 1995): 101-108	612
6	Jensen ME, Evans AJ, Mathis JM, Kallmes DF, Cloft HJ, Dion JE. "Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects," *AJNR* 18, no. 10 (December 1997): 1897-1904	529
7	Livraghi T, Goldberg SN, Lazzaroni S, Meloni F, Ierace T, Solbiati L, Gazelle GS. "Hepatocellular carcinoma: radio-frequency ablation of medium and large lesions," *Radiology* 214, no. 3 (March 2000): 761-768	516
8	Rossi S, Di Stasi M, Buscarini E, Quaretti P, Garbagnati F, Squassante L, Paties CT, Silverman DE, Buscarini L. "Percutaneous RF interstitial thermal ablation in the treatment of hepatic cancer," *AJR* 167, no. 3 (September 1996): 759-768	497
9	Parker SH, Burbank F, Jackman RJ, Aucreman CJ, Cardenosa G, Cink TM, Coscia JL Jr, Eklund GW, Evans WP 3rd, Garver PR "Percutaneous large-core breast biopsy: a multi-institutional study," *Radiology* 193, no. 2 (November 1994): 359-364	461
10	Hessel SJ, Adams DF, Abrams HL. "Complications of angiography," *Radiology* 138, no. 2 (February 1981): 273-281	448
11	H Deramond, Depriester C, Galibert P, Le Gars D. "Percutaneous vertebroplasty with polymethylmethacrylate. Technique, indications, and results," *Radiologic Clinics of North America* 36, no. 3 (May 1998): 533-546	432
12	L Solbiati, Livraghi T, Goldberg SN, Ierace T, Meloni F, Dellanoce M, Cova L, Halpern EF, Gazelle GS. "Percutaneous radio-frequency ablation of hepatic metastases from colorectal cancer: long-term results in 117 patients," *Radiology* 221, no. 1 (October 2001): 159-166	424
13	Livraghi T, Solbiati L, Meloni MF, Gazelle GS, Halpern EF, Goldberg SN. "Treatment of focal liver tumors with percutaneous radio-frequency ablation: complications encountered in a multicenter study," *Radiology* 226, no. 2 (February 2003): 441-451	421
14	Cotton A, Dewatre F, Cortet B, Assaker R, Leblond D, Duquesnoy B, Chastanet P, Clarisse J. "Percutaneous vertebroplasty for osteolytic metastases and myeloma: effects of the percentage of lesion filling and the leakage of methyl methacrylate at clinical follow-up," *Radiology* 200, no. 2 (August 1996): 525-530	417
15	LaBerge JM, Ring EJ, Gordon RL, Lake JR, Doherty MM, Somberg KA, Roberts JP, Ascher NL. "Creation of transjugular intrahepatic portosystemic shunts with the wallstent endoprosthesis: results in 100 patients," *Radiology* 187, no. 2 (May 1993): 413-420	410
16	Solbiati L, Goldberg SN, Ierace T, Livraghi T, Meloni F, Dellanoce M, Sironi S, Gazelle GS. "Hepatic metastases: percutaneous radio-frequency ablation with cooled-tip electrodes," *Radiology* 205, no. 2 (November 1997): 367-373	402
17	Riccardo RA, Allgaier HP, Cioni D, Olschewski M, Deibert P, Crocetti L, Frings H, Laubenberger J, Zuber I, Blum HE, Bartolozzi C. "Small hepatocellular carcinoma in cirrhosis: randomized comparison of radio-frequency thermal ablation versus percutaneous ethanol injection," *Radiology* 228, no. 1 (July 2003): 235-240	396
18	Judkins MP. "Percutaneous transfemoral selective coronary arteriography," *Radiologic Clinics of North America* 6, no. 3 (December 1968): 467-492	392
19	Rossi S, Buscarini E, Garbagnati F, Di Stasi M, Quaretti P, Rago M, Zangrandi A, Andreola S, Silverman D, Buscarini L. "Percutaneous treatment of small hepatic tumors by an expandable RF needle electrode," *AJR* 170, no. 4 (April 1998): 1015-1022	387
20	Gianturco C, Anderson JH, Wallace S. "Mechanical devices for arterial occlusion," *The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine* 124, no. 3 (July 1975): 428-435	384
21	Solbiati L, Ierace T, Goldberg SN, Sironi S, Livraghi T, Fiocca R, Servadio G, Rizzatto G, Mueller PR, Del Maschio A, Gazelle GS. "Percutaneous US-guided radio-frequency tissue ablation of liver metastases: treatment and follow-up in 16 patients," *Radiology* 202, no. 1 (January 1997): 195-203	378
22	Weill A, Chiras J, Simon JM, Rose M, Sola-Martinez T, Enkaoua E. "Spinal metastases: indications for and results of percutaneous injection of acrylic surgical cement," *Radiology* 199, no. 1 (April 1996): 241-247	356
23	Castaneda-Zuniga WR, Formanek A, Tadavarthy M, Vlodaver Z, Edwards JE, Zollikofer C, Amplatz K. "The mechanism of balloon angioplasty," *Radiology* 135, no. 3 (June 1980): 565-571	354
24	Goldberg SN, Gazelle GS, Mueller PR. "Thermal ablation therapy for focal malignancy: a unified approach to underlying principles, techniques, and diagnostic imaging guidance," *AJR* 174, no. 2 (February 2000): 323-331	349
25	Waugh JR, Sacharias N. "Arteriographic complications in the DSA era," *Radiology* 182, no. 1 (January 1992): 243-246	332
26	Heiserman JE, Dean BL, Hodak JA, Flom RA, Bird CR, Drayer BP, Fram EK. "Neurologic complications of cerebral angiography," *AJNR* 15, no. 8 (September 1994): 1401-1407; discussion 1408-1411	321
27	Gazelle GS, Goldberg SN, Solbiati L, Livraghi T. "Tumor ablation with radio-frequency energy," *Radiology* 217, no. 3 (December 2000): 633-646	321
28	Livraghi T, Goldberg SN, Monti F, Bizzini A, Lazzaroni S, Meloni F, Pellicanò S, Solbiati L, Gazelle GS. "Saline-enhanced radio-frequency tissue ablation in the treatment of liver metastases," *Radiology* 202, no. 1 (January 1997): 205-210	311
29	Smith EH. "Complications of percutaneous abdominal fine-needle biopsy. Review," *Radiology* 178, no. 1 (January 1991): 253-258	308
30	Parker SH. "Stereotactic breast biopsy with a biopsy gun," *Radiology* 176, no. 3 (September 1990): 741-747	306
31	Dodd GD, Soulen MC, Kane RA, Livraghi T, Lees WR, Yamashita Y, Gillams AR, Karahan OI, Rhim H "Minimally invasive treatment of malignant hepatic tumors: at the threshold of a major breakthrough," *Radiographics* 20, no. 1 (February 2000): 9-27	304
32	Livraghi T, Festi D, Monti F, Salmi A, Vettori C. "US-guided percutaneous alcohol injection of small hepatic and abdominal tumors," *Radiology* 161, no. 2 (November 1986): 309-312	295

33	Lang EK. "A survey of the complications of percutaneous retrograde arteriography: Seldinger Technic", *Radiology* 81 (August 1963): 257-263	292
34	Nakamura H, Hashimoto T, Oi H, Sawada S. "Transcatheter oily chemoembolization of hepatocellular carcinoma," *Radiology* 170, no. 3 Pt 1 (March 1989): 783-786	290
35	Rösch J, Dotter CT, Brown MJ. "Selective arterial embolization. A new method for control of acute gastrointestinal bleeding," *Radiology* 102, no. 2 (February 1972): 303-306	285
36	Shiina S, Tagawa K, Niwa Y, Unuma T, Komatsu Y, Yoshiura K, Hamada E, Takahashi M, Shiratori Y,Terano A. "Percutaneous ethanol injection therapy for hepatocellular carcinoma: results in 146 patients," *AJR* 160, no. 5 (May 1993): 1023-1028	283
37	Theron JG, Payelle GG, Coskun O, Huet HF, Guimaraens L. "Carotid artery stenosis: treatment with protected balloon angioplasty and stent placement," *Radiology* 201, no. 3 (December 1996): 627-636	283
38	Chilcote WA, Modic MT, Pavlicek WA, Little JR, Furlan AJ, Duchesneau PM, Weinstein MA. "Digital subtraction angiography of the carotid arteries: a comparative study in 100 patients," *Radiology* 139, no. 2 (May 1981): 287-295	268
39	Parker SH, Jobe WE, Dennis MA, Stavros AT, Johnson KK, Yakes WF, Truell JE, Price JG, Kortz AB, Clark DG. US-guided automated large-core breast biopsy, *Radiology* 187, no. 2 (May 1993): 507-511	268
40	McNamara TO, Fischer JR. "Thrombolysis of peripheral arterial and graft occlusions: improved results using high-dose urokinase," *AJR* 144, no. 4 (April 1985): 769-775	266
41	Goodwin SC, McLucas B, Lee M, Chen G, Perrella R, Vedantham S, Muir S, Lai A, Sayre JW, DeLeon M. "Uterine artery embolization for the treatment of uterine leiomyomata midterm results," *JVIR* 10, no. 9 (October 1999): 1159-1165	260
42	Grüntzig A, Kumpe DA. "Technique of percutaneous transluminal angioplasty with the Grüntzig ballon catheter," *AJR* 132, no. 4 (April 1979): 547-552	259
43	Rossi S, Garbagnati F, Lencioni R, Allgaier HP, Marchianò A, Fornari F, Quaretti P, Tolla GD, Ambrosi C,Mazzaferro V, Blum HE, Bartolozzi C. "Percutaneous radio-frequency thermal ablation of nonresectable hepatocellular carcinoma after occlusion of tumor blood supply," *Radiology* 217, no. 1 (October 2000): 119-126	257
44	Goldstein HM, Wallace S, Anderson JH, Bree RL, Gianturco C. "Transcatheter occlusion of abdominal tumors," *Radiology* 120, no. 3 (September 1976): 539-545	257
45	Cotton A, Boutry N, Cortet B, Assaker R, Demondion X, Leblond D, Chastanet P, Duquesnoy B,Deramond H. "Percutaneous vertebroplasty: state of the art," *Radiographics* 18, no. 2 (April 1998): 311-320	257
46	vanSonnenberg E, Mueller PR, Ferrucci Jr JT. "Percutaneous drainage of 250 abdominal abscesses and fluid collections. Part I: Results, failures, and complications," *Radiology* 151, no. 2 (May 1984): 337-341	256
47	Krepel VM, van Andel GJ, van Erp WF, Breslau PJ. "Percutaneous transluminal angioplasty of the femoropopliteal artery: initial and long-term results," *Radiology* 156, no. 2 (August 1985): 325-328	255
48	Goldberg SN, Gazelle GS, Solbiati L, Rittman WJ, Mueller PR. "Radiofrequency tissue ablation: increased lesion diameter with a perfusion electrode," *Academic Radiology* 3, no. 8 (August 1996): 636-644	254
49	Mewissen MW, Seabrook GR, Meissner MH, Cynamon J, Labropoulos N, Haughton SH. "Catheter-directed thrombolysis for lower extremity deep venous thrombosis: report of a national multicenter registry," *Radiology* 211, no. 1 (April 1999): 39-49	254
50	Baum S, Nusbaum M. "The control of gastrointestinal hemorrhage by selective mesenteric arterial infusion of vasopressin," *Radiology* 98, no. 3 (March 1971): 497-505	253
51	White Jr RI, Lynch-Nyhan A, Terry P, Buescher PC, Farmlett EJ, Charnas L, Shuman K, Kim W, Kinnison M, Mitchell SE. "Pulmonary arteriovenous malformations: techniques and long-term outcome of embolotherapy," *Radiology* 169, no. 3 (December 1988): 663-669	251
52	Goldberg SN, Solbiati L, Hahn PF, Cosman E, Conrad JE, Fogle R, Gazelle GS. "Large-volume tissue ablation with radio frequency by using a clustered, internally cooled electrode technique: laboratory and clinical experience in liver metastases," *Radiology* 209, no. 2 (November 1998): 371-379	251
53	Chuang VP, Wallace S. "Hepatic artery embolization in the treatment of hepatic neoplasms," *Radiology* 140, no. 1 (July 1981): 51-58	249
54	Goldberg SN, Hahn PF, Tanabe KK, Mueller PR, Schima W, Athanasoulis CA, Compton CC, Solbiati L,Gazelle GS. "Percutaneous radiofrequency tissue ablation: does perfusion-mediated tissue cooling limit coagulation necrosis?," *JVIR* 9, no. 1 Pt 1 (February 1998): 101-111	249
55	McAffe JG. "A survey of complications of abdominal aortography," *Radiology* 68, no. 6 (June 1957): 825-838	248
56	Johnston KW. "Femoral and popliteal arteries: reanalysis of results of balloon angioplasty," *Radiology* 183, no. 3 (June 1992): 767-771	248
57	Willinsky RA, Taylor SM, TerBrugge K, Farb RI, Tomlinson G, Montanera W. "Neurologic complications of cerebral angiography: prospective analysis of 2,899 procedures and review of the literature," *Radiology* 227, no. 2 (May 2003): 522-528	248
58	Dupuy DE, Zagoria RJ, Akerley W, Mayo-Smith WW, Kavanagh PV, Safran H. "Percutaneous radiofrequency ablation of malignancies in the lung," *AJR* 174, no. 1 (January 2000): 57-59	245
59	Vogl TJ, Müller PK, Hammerstingl R, Weinhold N, Mack MG, Philipp C, Deimling M, Beuthan J, Pegios W, Riess H, et al. "Malignant liver tumors treated with MR imaging-guided laser-induced thermotherapy: technique and prospective results," *Radiology* 196, no. 1 (July 1995): 257-265	244
60	Becker GJ, Katzen BT, Dake MD. "Noncoronary angioplasty," *Radiology* 170, no. 3 Pt 2 (March 1989): 921-940	241
61	Ferrucci Jr JT, Wittenberg J, Mueller PR, Simeone JF, Harbin WP, Kirkpatrick RH, Taft PD."Diagnosis of abdominal malignancy by radiologic fine-needle aspiration biopsy," *AJR* 134, no. 2 (February 1980): 323-330	239
62	Min RJ, Khilnani N, Zimmet SE. "Endovenous laser treatment of saphenous vein reflux: long-term results," *JVIR* 14, no. 8 (August 2003): 991-996	238
63	Gerzof SG, Robbins AH, Birkett DH, Johnson WC, Pugatch RD, Vincent ME. "Percutaneous catheter drainage of abdominal abscesses guided by ultrasound and computed tomography," *AJR* 133, no. 1 (July 1979): 1-8	237
64	Haaga JR, Alfidi RJ. "Precise biopsy localization by computer tomography," *Radiology* 118, no. 3 (March 1976): 603-607	236
65	Lencioni R, Cioni D, Crocetti L, Franchini C, Pina CD, Lera J, Bartolozzi C. "Early-stage hepatocellular carcinoma in patients with cirrhosis: long-term results of percutaneous image-guided radiofrequency ablation," *Radiology* 234, no. 3 (March 2005): 961-967	233
66	Mueller PR, van Sonnenberg E, Ferrucci Jr JT. "Percutaneous biliary drainage: technical and catheter-related problems in 200 procedures," *AJR* 138, no. 1 (January 1982): 17-23	232

67	de Baere T, Elias D, Dromain C, Din MG, Kuoch V, Ducreux M, Boige V, Lassau N, Marteau V, Lasser P,Roche A. "Radiofrequency ablation of 100 hepatic metastases with a mean follow-up of more than 1 year," *AJR* 175, no. 6 (December 2000): 1619-1625	232
68	Ferrucci Jr JT, Mueller PR, Harbin WP. "Percutaneous transhepatic biliary drainage: technique, results, and applications," *Radiology* 135, no. 1 (April 1980): 1-13	231
69	Khouri NF, Stitik FP, Erozan YS, Gupta PK, Kim WS, Scott WW Jr, Hamper UM, Mann RB, Eggleston JC,Baker RR. "Transthoracic needle aspiration biopsy of benign and malignant lung lesions," *AJR* 144, no. 2 (February 1985): 281-288	230
70	Meaney TF, Weinstein MA, Buonocore E, Pavlicek W, Borkowski GP, Gallagher JH, Sufka B, MacIntyre WJ "Digital subtraction angiography of the human cardiovascular system," *AJR* 135, no. 6 (December 1980): 1153-1160	229
71	Padovani B, Kasriel O, Brunner P, Peretti-Viton P. "Pulmonary embolism caused by acrylic cement: a rare complication of percutaneous vertebroplasty," *AJNR* 20, no. 3 (March 1999): 375-377	229
72	Palmaz JC, Laborde JC, Rivera FJ, Encarnacion CE, Lutz JD, Moss JG. "Stenting of the iliac arteries with the Palmaz stent: experience from a multicenter trial" *Cardiovascular and Interventional Radiology* 15, no. 5 (October 1992): 291-297	228
73	Matsui O, Kadoya M, Yoshikawa J, Gabata T, Arai K, Demachi H, Miyayama S, Takashima T, Unoura M, Kogayashi K. "Small hepatocellular carcinoma: treatment with subsegmental transcatheter arterial embolization," *Radiology* 188, no. 1 (July 1993): 79-83	228
74	Elvecrog EL, Lechner MC, Nelson MT. "Nonpalpable breast lesions: correlation of stereotaxic large-core needle biopsy and surgical biopsy results," *Radiology* 188, no. 2 (August 1993): 453-455	228
75	Burbank F. "Stereotactic breast biopsy of atypical ductal hyperplasia and ductal carcinoma in situ lesions: improved accuracy with directional, vacuum-assisted biopsy," *Radiology* 202, no. 3 (March 1997): 843-847	228
76	Molnar W, Stockum AE. "Relief of obstructive jaundice through percutaneous transhepatic catheter--a new therapeutic method," The American Journal of Roentgenology, *Radium Therapy*, and *Nuclear Medicine* 122, no. 2 (October 1974): 356-367	227
77	Rémy J, Arnaud A, Fardou H, Giraud R, Voisin C. "Treatment of hemoptysis by embolization of bronchial arteries," *Radiology* 122, no. 1 (January 1977): 33-37	226
78	Gangi A, Kastler BA, Dietemann JL. "Percutaneous vertebroplasty guided by a combination of CT and fluoroscopy," *AJNR* 15, no. 1 (January 1994): 83-86	226
79	Haaga JR, Alfidi RJ, Havrilla TR, Cooperman AM, Seidelmann FE, Reich NE, Weinstein AJ, Meaney TF. "CT detection and aspiration of abdominal abscesses," *AJR* 128, no. 3 (March 1977): 465-474	225
80	Earnest F 4th, Forbes G, Sandok BA, Piepgras DG, Faust RJ, Ilstrup DM, Arndt LJ. "Complications of cerebral angiography: prospective assessment of risk," *AJR* 142, no. 2 (February 1984): 247-253	225
81	Amin Z, Donald JJ, Masters A, Kant R, Steger AC, Bown SG, Lees WR. "Hepatic metastases: interstitial laser photocoagulation with real-time US monitoring and dynamic CT evaluation of treatment," *Radiology* 187, no. 2 (May 1993): 339-347	223
82	Mills SR, Jackson DC, Older RA, Heaston DK, Moore AV. "The incidence, etiologies, and avoidance of complications of pulmonary angiography in a large series," *Radiology* 136, no. 2 (August 1980): 295-299	222
83	vanSonnenberg E, Ferrucci JT Jr, Mueller PR, Wittenberg J, Simeone JF. "Percutaneous drainage of abscesses and fluid collections: technique, results, and applications," *Radiology* 142, no. 1 (January 1982): 1-10	221
84	Richter GM, Noeldge G, Palmaz JC, Roessle M, Slegerstetter V, Franke M, Gerok W, Wenz W, Farthman E. "Transjugular intrahepatic portacaval stent shunt: preliminary clinical results," *Radiology* 174, no. 3 Pt 2 (March 1990): 1027-1030	219
85	Zeumer H, Freitag HJ, Zanella F, Thie A, Arning C. "Local intra-arterial fibrinolytic therapy in patients with stroke: urokinase versus recombinant tissue plasminogen activator (r-TPA)," *Neuroradiology* 35, no. 2 (1993): 159-162	219
86	Westcott JL. "Direct percutaneous needle aspiration of localized pulmonary lesions: result in 422 patients," *Radiology* 137, no. 1 Pt 1 (October 1980): 31-35	216
87	Cognard C, Weill A, Spelle L, Piotin M, Castaings L, Rey A, Moret J. "Long-term angiographic follow-up of 169 intracranial berry aneurysms occluded with detachable coils," *Radiology* 212, no. 2 (August 1999): 348-356	216
88	Cammà C, Schepis F, Orlando A, Albanese M, Shahied L, Trevisani F, Andreone P, Craxì A, Cottone M. "Transarterial chemoembolization for unresectable hepatocellular carcinoma: meta-analysis of randomized controlled trials," *Radiology* 224, no. 1 (July 2002): 47-54	215
89	Goodwin SC, Vedantham S, McLucas B, Forno AE, Perrella R. "Preliminary experience with uterine artery embolization for uterine fibroids," *JVIR* 8, no. 4 (August 1997): 517-526	211
90	Goldberg SN, Gazelle GS, Dawson SL, Rittman WJ, Mueller PR, Rosenthal DI. "Tissue ablation with radiofrequency: effect of probe size, gauge, duration, and temperature on lesion volume," *Academic Radiology* 2, no. 5 (May 1995): 399-404	208
91	McGhana JP, Dodd GD, 3rd, "Radiofrequency ablation of the liver: current status," *AJR* 176, no. 1 (January 2001): 3-16	207
92	Mani RL, Eisenberg RL, McDonald EJ Jr, Pollock JA, Mani JR. "Complications of catheter cerebral arteriography: analysis of 5,000 procedures. I. Criteria and incidence," *AJR* 131, no. 5 (November 1978): 861-865	206
93	Katzen BT, van Breda A. "Low dose streptokinase in the treatment of arterial occlusions," *AJR* 136, no. 6 (June 1981): 1171-1178	206
94	Goldberg, Grassi CJ, Cardella JF, Charboneau JW, Dodd GD 3rd, Dupuy DE, Gervais D, Gillams AR,Kane RA, Lee FT Jr, Livraghi T, McGahan J, Phillips DA, Rhim H, Silverman SG "Image-guided tumor ablation: standardization of terminology and reporting criteria," *Radiology* 235, no. 3 (June 2005): 728-739	205
95	Gervais DA, McGovern FJ, Arellano RS, McDougal WS, Mueller PR. "Renal cell carcinoma: clinical experience and technical success with radio-frequency ablation of 42 tumors," *Radiology* 226, no. 2 (February 2003): 417-424	204
96	Bookstein JJ, Goldstein HM. "Successful management of postbiopsy arteriovenous fistula with selective arterial embolization," *Radiology* 109, no. 3 (December 1973): 535-536	203
97	Jackman RJ, Nowels KW, Rodriguez-Soto J, Marzoni FA Jr, Finkelstein SI, Shepard MJ. "Stereotactic, automated, large-core needle biopsy of nonpalpable breast lesions: false-negative and histologic underestimation rates after long-term follow-up," *Radiology* 210, no. 3 (March 1999): 799-805	202
98	Dupuy DE, Goldberg SN. "Image-guided radiofrequency tumor ablation: challenges and opportunities--part II," *JVIR* 12, no. 10 (October 2001): 1135-1148	202
99	Ferris EJ, McCowan TC, Carver DK, McFarland DR. "Percutaneous inferior vena caval filters: follow-up of seven designs in 320 patients," *Radiology* 188, no. 3 (September 1993): 851-856	200
100	Worthington-Kirsch RL, Popky GL, Hutchins Jr FL. "Uterine arterial embolization for the management of leiomyomas: quality-of-life assessment and clinical response," *Radiology* 208, no. 3 (September 1998): 625-629	200

Table 3 Summary of characteristics of 100 most cited papers

Year of publication		Country of origin		Institution of origin		Journal of publication		Named author	
Year	No. pubs.	Country	No. pubs	Institution	No pubs.	Journal	No. pubs.	Author	No. pubs.
1950's	2	United States	67	Harvard Uni.	18	*Radiology*	62	Goldberg SN	15
1960's	3	Italy	20	Osped Civile	11	*AJR*	20	Gazelle GS	13
1970's	12	France	10	Mass.Gen.	9	*JVIR*	5	Livraghi T	12
1980's	22	Germany	5	Osped Gen.	8	*AJNR*	4	Mueller PR	11
1990's	43	Japan	5	Beth Israel	8	*Academic Radiology*	2	Solbiati L	11
2000 -	18	Canada	2	Univ Texas	6	*Radiographics*	2	Ferrucci FT	5

by the oldest papers; secondly very recently published papers will not be included in this list as, despite their scientific originality and impact, they have not had time to accumulate sufficient citations. Whilst it is reassuring that older doesn't necessarily mean more cited, the fact that recently published papers are inherently excluded from citation analysis demonstrates one of its major flaws. Another limitation of citation analysis is the process of "obliteration by incorporation"[10]. This describes the phenomenon where information from landmark papers becomes incorporated and absorbed into current knowledge and thus these papers are not explicitly cited. For this reason it has been noted that many true "classic papers" and seminal works in a particular field are not found in the most cited list itself but rather in the reference lists of the most cited papers.

This list is dominated by the United States with 67 papers in the top 100. This correlates with similar studies in other fields such as dermatology[11] (United States = 75%), general surgery[12] (United States = 78%) and orthopaedics[5] (United States = 77%). It reflects the huge influence of the United States on medical research and the massive scientific output of the country. It has also been noted that there is a tendency for American authors to preferentially cite other papers from the United States and this is likely to increase their dominance[7,13]. In fact interventional radiology appears to be less dominated by the United States than other specialties with significant contributions from the European power houses of Italy (n = 20) and France (n = 10).

All papers were published in only 10 journals. With 60 publications in the top 100 *Radiology* is by far the most prolific publisher followed by the *American Journal of Roentgenology (AJR)* with 20 publications. Most papers are published in general radiology journals with only a handful (n = 6) published in the two specific interventional journals in the list – *Cardiovascular and Interventional Radiology* and the *Journal of Vascular and Interventional Radiology.* However this is likely to reflect relatively recent emergence of specialised interventional radiology journals (1977 and 1990 respectively) when compared to the traditional pre eminent radiology journals such as *Radiology* and the *AJR.*

One flaw of this study is that, due to technological limitations of the database of Journal Citation Reports, the search for papers was limited to specialist radiology journals. This meant that papers published in non-radiology journals would not be included in this "top 100 list". This is particularly relevant when considering older papers which would have been more likely to have been published in non specialist radiology journals.

Citation bias towards authors of the same nationality has already been discussed. Other limitations of this study can be linked to the inherent weakness of using citation rate alone in measuring a paper's strength. Instead of using a citation to give credit to those who have significantly influenced their work, some authors use citations to support their own results or to persuade the reader towards a particular conclusion, a process known as incomplete citing[14]. Many other biases are recognised which might influence the citation of papers. These include self or in house citation bias, bias towards citing review articles over original research and English language bias.

It is clear from discussion of the flaws and limitations of this study, as well as the biases inherent in the field of citation analysis, that the number of citations that a paper receives should not be used alone as a measure of its scientific quality[1,15]. However it is also clear that the citation rate of a paper is one of many useful tools in measuring the recognition that a paper has received and therefore the impact that a paper has had on its specialty[16], Whilst this list of citation classics in interventional radiology should not be considered the definitive "top 100" of this specialty, it does reveal many landmark papers and identifies many of the topics, authors and institutions which have dominated the specialty over the last sixty years.

This is the first study to use citation analysis in an attempt to identify the research papers which have had the greatest impact on the specialty of interventional radiology. Although citation analysis does have limitations, many of the seminal papers of interventional radiology and pioneers of the field are included in this list of "100 citation classics".

COMMENTS

Background

The value of a scientific paper may be defined by its impact on the biomedical

field in which it is published. Papers which impact greatly on their field may achieve the status of a "classic paper". This may be defined using the concept of a citation classic - the number of times a paper is cited reflects its impact and relevance. The aim of this study was to define the top 100 citation classics of the rapidly evolving specialty of interventional radiology and in the process identify the topics, authors and institutions that have impacted greatly on this rapidly evolving specialty.

Research frontiers

Interventional radiology is a young and rapidly evolving specialty. For the last 40 years interventional radiologists have been at the vanguard of innovation with the development of numerous minimally invasive procedures which have revolutionised patient management in multiple areas. The speciality has rapidly grown and evolved from its origins with Seldinger's refinement of arterial cannulisation and Dodder's development of angioplasty and the catheter delivered stents. Embolization of arterial haemorrhage in trauma, catheter directed thrombolysis and coiling of aneurysms are now the gold standard treatments in their respective areas. Recent advances in the specialty include drug eluting balloons and stents in peripheral vascular disease, microwave tumor ablation for liver, kidney and lung tumors and transarterial catheter directed chemotherapy or radionuclide therapy in primary liver tumors and metastases. This study has used citation analysis to define many of the seminal papers within interventional radiology.

Innovations and breakthroughs

This is the first study which has used citation analysis in an attempt to define the most innovative and significant papers in interventional radiology and those which have had the most significant impact on this field. Although citation analysis does have limitations, many of the seminal papers of interventional radiology are included in this list of "100 citation classics".

Applications

This study has used citation analysis to identify the 100 classic papers of interventional radiology. These papers included many of the seminal works in this field by many of the pioneers of the specialty providing a fascinating discourse on the evolution and development of interventional radiology.

Terminology

IR: Interventional radiology.

Peer-review

Nice paper with good analyses.

REFERENCES

1 **Marx WSH**, Wanitschek M. Citation analysis using online databases: feasibilities and shortcomings. *Scientometrics* 2001; **52**: 59-82 [DOI: 10.1023/A: 1012798911792]

2 **Seglen PO**. Citation frequency and journal impact: valid indicators of scientific quality? *J Intern Med* 1991; **229**: 109-111 [PMID: 1997634]

3 **Hall GM**. BJA citation classics 1945-1992. *Br J Anaesth* 1998; **80**: 4-6 [PMID: 9505768]

4 **Heldwein FL**, Rhoden EL, Morgentaler A. Classics of urology: a half century history of the most frequently cited articles (1955-2009). *Urology* 2010; **75**: 1261-1268 [PMID: 19962736]

5 **Kelly JC**, Glynn RW, O'Briain DE, Felle P, McCabe JP. The 100 classic papers of orthopaedic surgery: a bibliometric analysis. *J Bone Joint Surg Br* 2010; **92**: 1338-1343 [PMID: 20884968]

6 **Li Z**, Wu FX, Yang LQ, Sun YM, Lu ZJ, Yu WF. Citation classics in main pain research journals. *J Anesth* 2012; **26**: 85-93 [PMID: 22008797]

7 **Seglen PO**. Citation rates and journal impact factors are not suitable for evaluation of research. *Acta Orthop Scand* 1998; **69**: 224-229 [PMID: 9703393]

8 **Goldberg SN**, Grassi CJ, Cardella JF, Charboneau JW, Dodd GD, Dupuy DE, Gervais D, Gillams AR, Kane RA, Lee FT, Livraghi T, McGahan J, Phillips DA, Rhim H, Silverman SG. Image-guided tumor ablation: standardization of terminology and reporting criteria. *J Vasc Interv Radiol* 2005; **16**: 765-778 [PMID: 15947040]

9 **Ravina JH**, Merland JJ, Ciraru-Vigneron N, Bouret JM, Herbreteau D, Houdart E, Aymard A. [Arterial embolization: a new treatment of menorrhagia in uterine fibroma]. *Presse Med* 1995; **24**: 1754 [PMID: 8545421]

10 **Picknett T**, Davis K. The 100 most-cited articles from JMB. *J Mol Biol* 1999; **293**: 171-176 [PMID: 10529345]

11 **Dubin D**, Häfner AW, Arndt KA. Citation classics in clinical dermatologic journals. Citation analysis, biomedical journals, and landmark articles, 1945-1990. *Arch Dermatol* 1993; **129**: 1121-1129 [PMID: 8363395]

12 **Paladugu R**, Schein M, Gardezi S, Wise L. One hundred citation classics in general surgical journals. *World J Surg* 2002; **26**: 1099-1105 [PMID: 12209239]

13 **Paris G**, De Leo G, Menozzi P, Gatto M. Region-based citation bias in science. *Nature* 1998; **396**: 210 [PMID: 10744503]

14 **Cole S**. Citations and the evaluation of individual scientists. *Trends Biochem Sci* 1989; **14**: 9-13 [DOI: 10.1016/0968-0004(89)90078-9]

15 **Braun T**. The reliability of total citation rankings. *J Chem Inf Comput Sci* 2003; **43**: 45-46 [PMID: 12546536]

16 **Dumont JE**. The bias of citations. *Trends Biochem Sci* 1989; **14**: 327-328 [PMID: 2799904]

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